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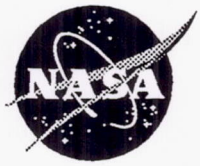

Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-79

Jill D. Lin

Technical Memorandum 111885 October1996

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DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS OF SHUTTLE MISSION STS-79

16 September 1996

Contributions By:

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

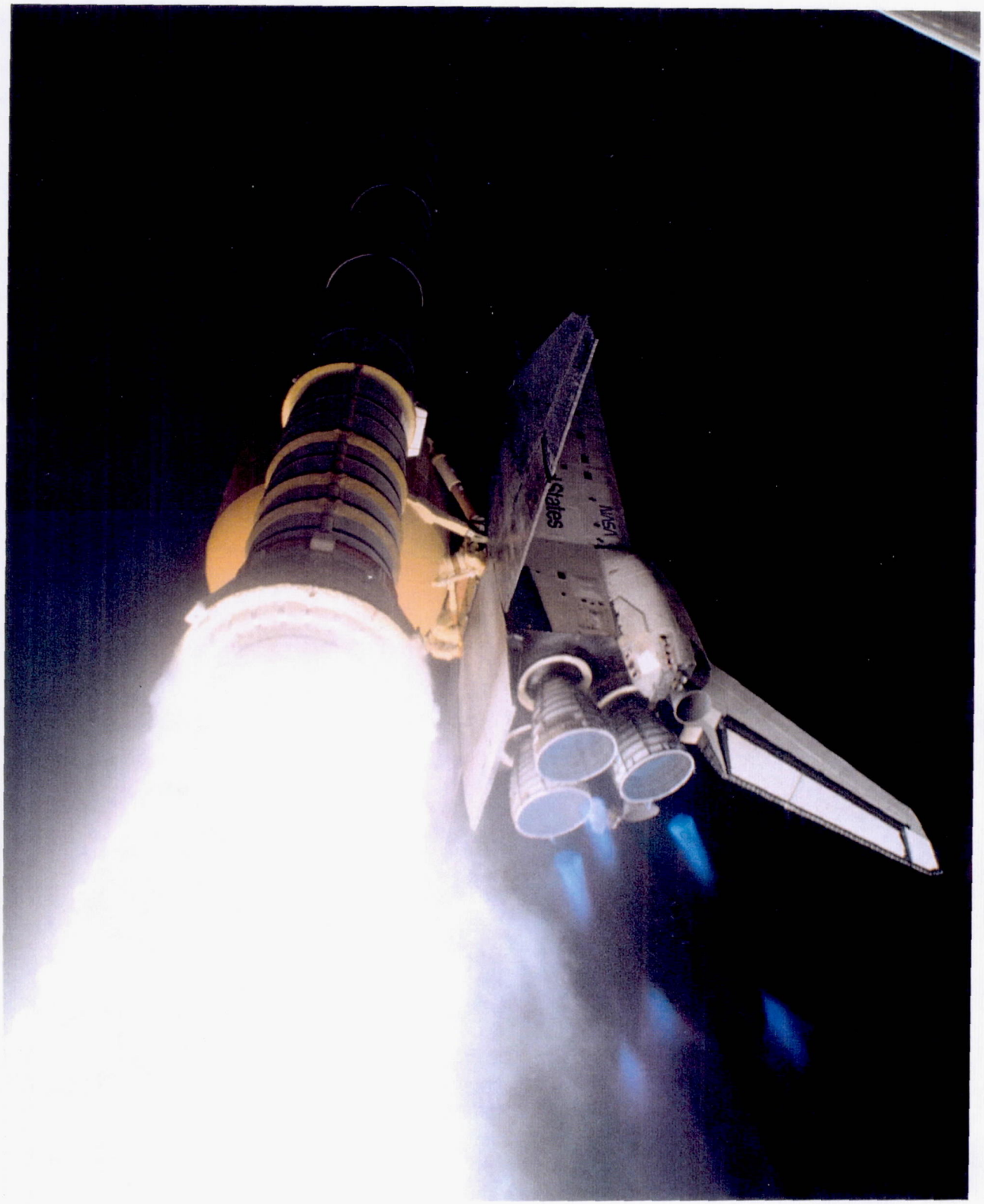


Photo 1: Launch of Shuttle Mission STS-79

1.0 SUMMARY

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 15 September 1996. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (20th flight), ET-82 (LWT 75), and BI-083 SRB's. There were no significant vehicle or pad anomalies.

The vehicle was cryoloaded for flight on 15 September 1996. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. No acreage icing or frost conditions were expected due to the time of year. There were no ice/frost conditions or protuberance icing conditions outside of the established data base.

After the 4:54 a.m. (local) launch on 16 September 1996, a debris walk down of Pad 39A was performed. No flight hardware or TPS materials were found. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 108 films and videos were analyzed as part of the post mission data review. No vehicle damage or lost flight hardware was observed that would have affected the mission.

A stud hang-up occurred on holddown post #3. No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view. No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts.

Orbiter umbilical camera films showed nominal separation of SRB's from the External Tank. No data was obtained during ET separation from the Orbiter due to dark conditions. Handheld photography by the flight crew showed PDL foam missing from two places (4-inch and 2-inch diameters, respectively) on the -Y aft fairing splice plate closeout. Depth was estimated to be no greater than 0.5-inches.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. The number of MSA-2 debonds on the left and right frustums were less than average. A 7/16 inch combination wrench was found inside the right SRB forward skirt. Except for the vendor name, no other markings were present on the wrench. An investigation team concluded that the wrench was most probably left in the forward skirt during manufacturing activities and was not discovered during the final turnover inspection, prior to delivery to SFOC or during the final close-out inspection, at the Pad, performed by SFOC. Recommendations were made to enhance inspection procedures at all USBI and SFOC SRB inspection points and to improve the USBI tool control system at the manufacturing facility.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-104 was conducted 26 September 1996 on SLF runway 15 at the Kennedy Space Center. The Orbiter TPS sustained a total of 103 hits, of which 11 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of hits and the number of hits 1-inch or larger was less than average.

The Orbiter lower surface sustained a total of 65 hits, of which 8 had a major dimension of 1-inch or larger. The largest lower surface tile damage site was located outboard and aft of the right main landing gear door and measured 6.0-inches long by 1.0-inches wide by 0.125-inch maximum depth. The damage was most likely caused by an ice impact from the ET LO2 feedline bellows and support brackets.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly.

A white tile (V070-39143-080-008507) above window #1 had a piece approximately 2.5-inches by 1.5-inches by 1.0-inch missing from the forward-most corner of the tile. Filler bar was visible and a part of the Strain Isolation Pad (SIP) appeared to be missing.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 13 September 1996 at 1400 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC	Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
J. Lin	NASA - KSC	Shuttle Ice/Debris Systems
B. Davis	NASA - KSC	Digital Imaging Systems
R. Speece	NASA - KSC	Thermal Protection Systems
B. Bowen	NASA - KSC	Infrared Scanning Systems
J. Rivera	NASA - KSC	ET Mechanisms/Structures
M. Bassignani	NASA - KSC	ET Mechanisms/Structures
Z. Byrns	NASA - KSC	Level II Integration
M. Valdivia	USA - SPC	Supervisor, ET/SRB Mechanical Systems
R. Seale	USA - SPC	ET Mechanical Systems
J. Blue	USA - SPC	ET Mechanical Systems
W. Richards	USA - SPC	ET Mechanical Systems
M. Wollam	USA - SPC	ET Mechanical Systems
G. Fales	USA - SPC	ET Mechanical Systems
K. Mayer	Rockwell LSS	Systems Integration
W. Atkinson	Rockwell LSS	Systems Integration
J. Cook	THIO - LSS	SRM Processing
J. Ramirez	LMSO - LSS	ET Processing

3.0 LAUNCH

STS-79 was launched at 96:260:08:54:49.009 GMT (4:54 a.m. local) on 16 September 1996.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on 15 September 1996. The detailed walkdown of Pad 39A and MLP-1 also included the primary flight elements OV-104 Atlantis (20th flight), ET-82 (LWT 75), and BI-083 SRB's. There were no significant vehicle or launch pad anomalies.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 15-16 September 1996 from 2250 to 0026 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No Ice, Debris, or TPS IPR's were taken. No acreage icing or frost conditions were expected due to the ambient conditions at this time of year. There were no protuberance icing conditions outside of the established data base.

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, particularly those areas not visible from remote fixed scanners, and to scan for unusual temperature gradients.

3.2.1 ORBITER

No Orbiter tile or RCC panel anomalies were observed. The F3L, R1R, R2R, and L4L RCS thruster covers were tinted green indicating small internal vapor leaks. No ice/frost had formed on the SSME heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.2.2 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the STI radiometers averaged 79-80 degrees F. Temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 81-84 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature supplied by THIO was 79 degrees F, which was within the required range of 44-86 degrees F.

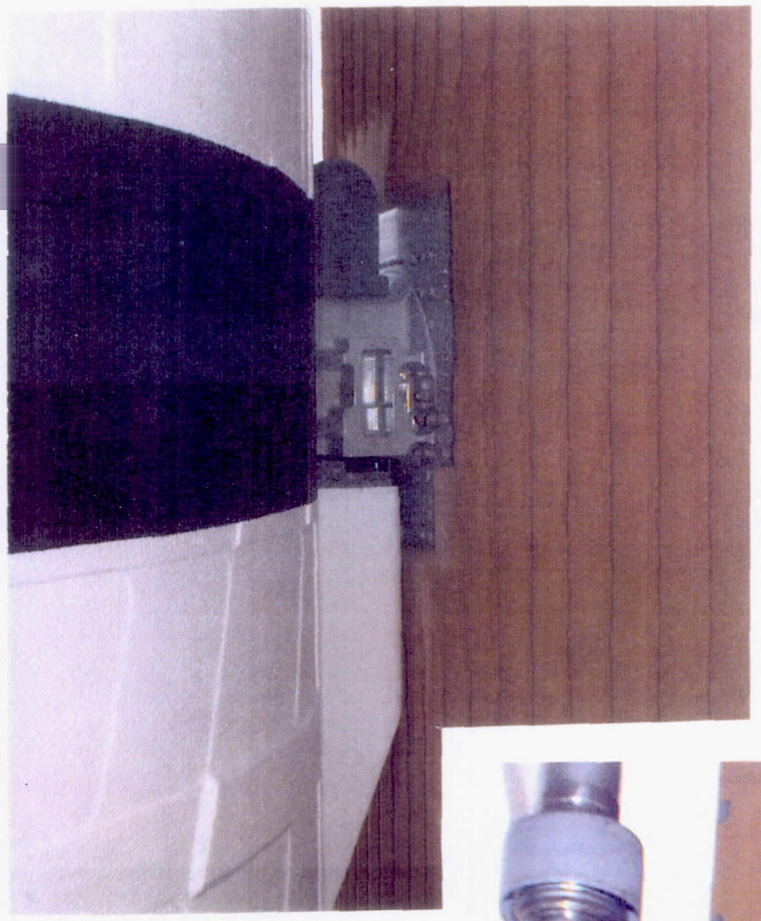
3.2.3 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run as a general comparison to infrared scanner point measurements. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures ranged from 67-71 degrees F.

The intertank acreage exhibited no TPS anomalies. Ice/frost accumulation on the GUCP was less than usual. Condensate had formed on the ET intertank door. ET-82 was the first flight that utilized the new composite intertank door.

As a weight-savings measure and process improvement, topcoat (Flame Retardant Latex) was not applied to the ET/SRB Forward Bolt Catcher, ET/ORB LH2 Umbilical Cable Tray, and parts of the LH2 Tank Cable Tray.



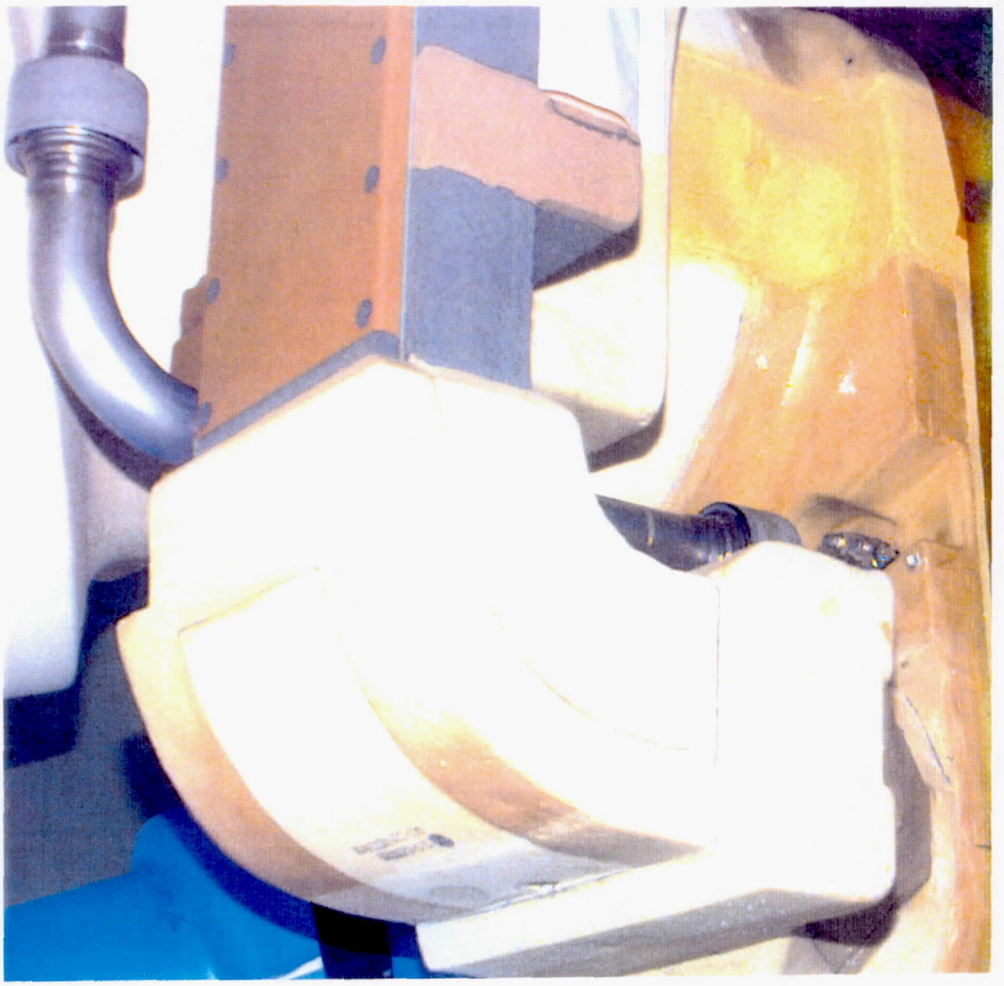


Photo 2: SRB/ET Bolt Catcher and ET LH2 Umbilical Cable Tray

As a weight-savings measure and process improvement, topcoat (Flame Retardant Latex) was not applied to the ET/SRB Bolt Catcher and the ET LH2 Umbilical Cable Tray.

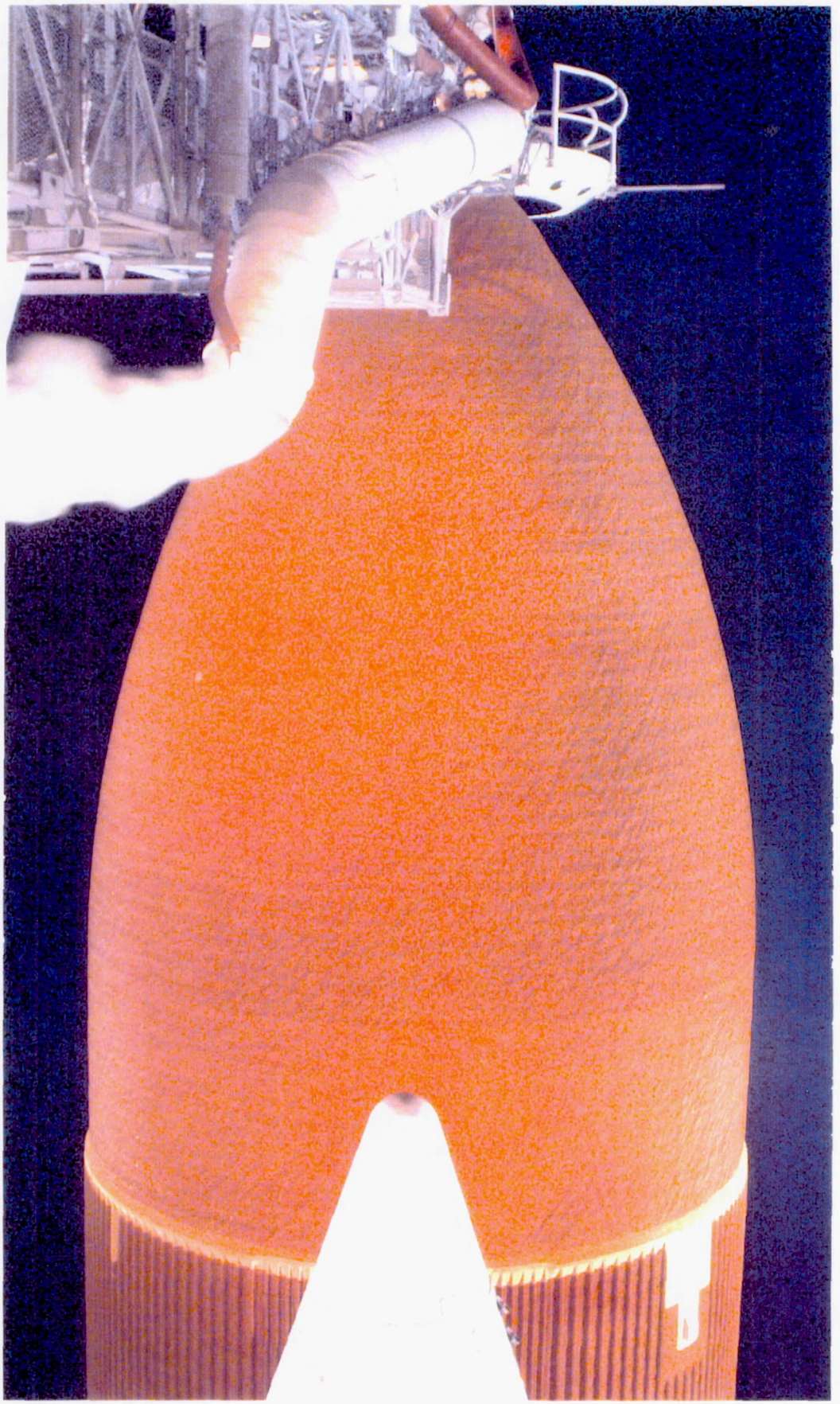


Photo 3: ET LO2 Tank

The Final Inspection Team observed light condensate, but no ice or frost accumulations, on the LO2 tank. TPS surface temperatures ranged from 67-71 degrees F.

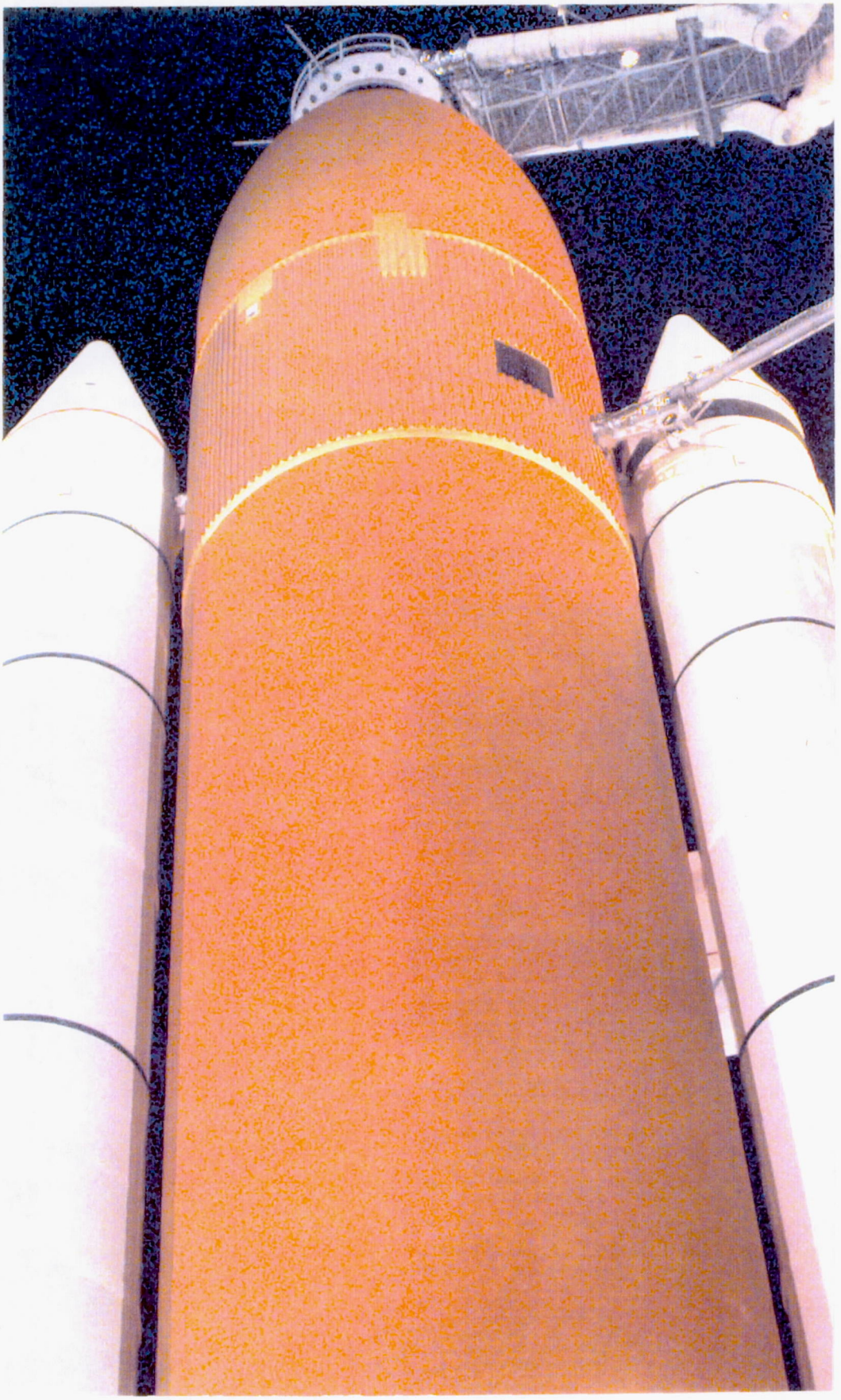


Photo 4: ET Cryoloaded for Launch

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulation, was present on the acreage. TPS surface temperatures ranged from 77-79 deg. F. ET-82 was the first flight that utilized the new composite Intertank door.

Photo 5: STS-79 Cryoloaded for Launch

OV-104 Atlantis (20th Flight), ET-82 (LWT 75), and BI-083 SRB's

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost accumulation, was present on the acreage. TPS surface temperatures ranged from 77-79 degrees F. There were no anomalies on the new method bipod jack pad standoff closeouts. A crack, 3-inches long by 1/4-inch wide, was present in the -Y vertical strut attachment fitting fairing forward surface TPS. The presence of the crack was acceptable for flight per NSTS-08303 criteria.

Less than usual amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers were present on the pyro canister and plate gap purge vents. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, included one OTV recorded item.

3.2.4 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch.

No leaks were observed on the GUCP or either of the LO2 and LH2 Orbiter T-0 umbilicals.

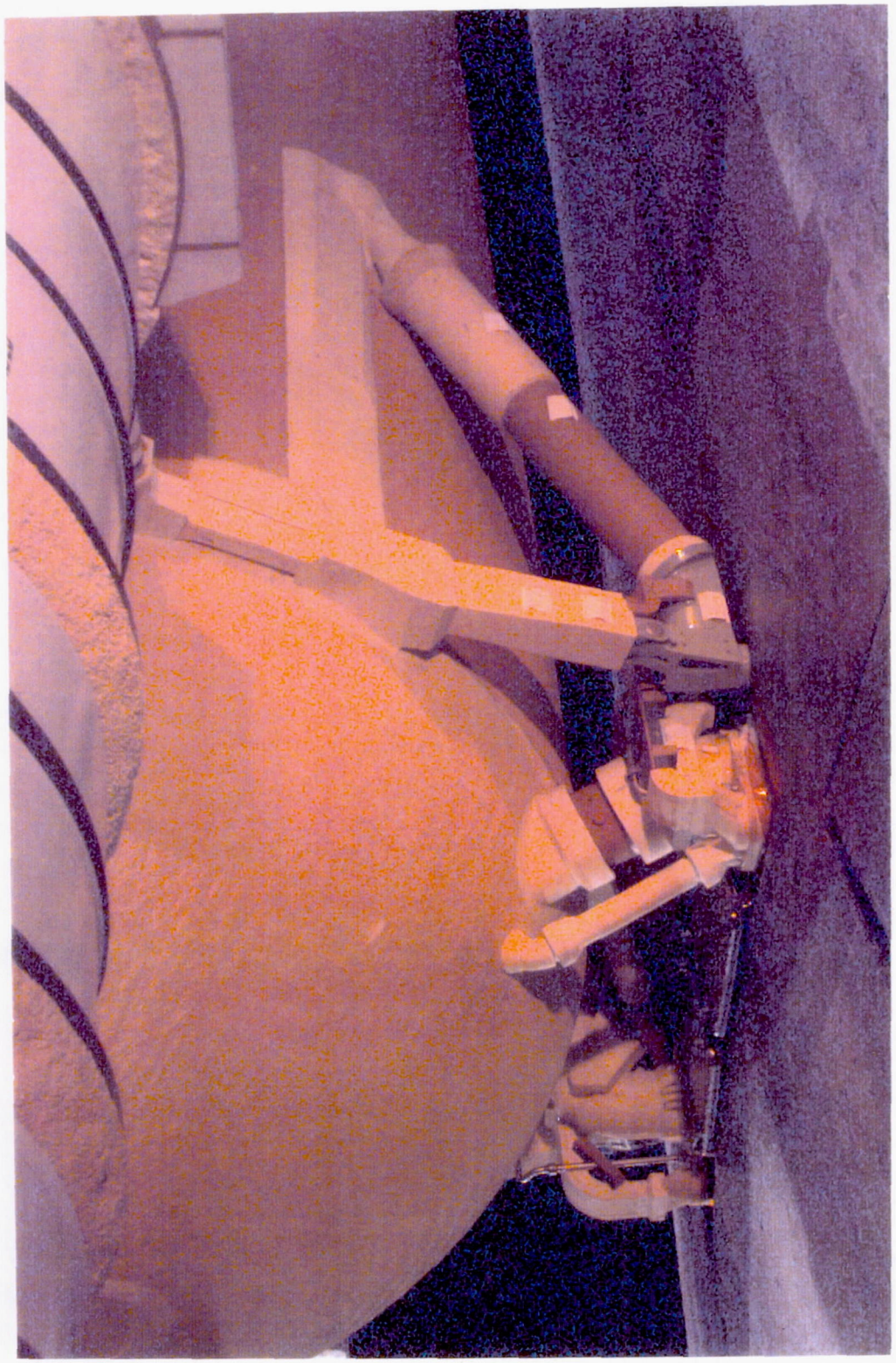


Photo 6: ET/ORB Umbilicals

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

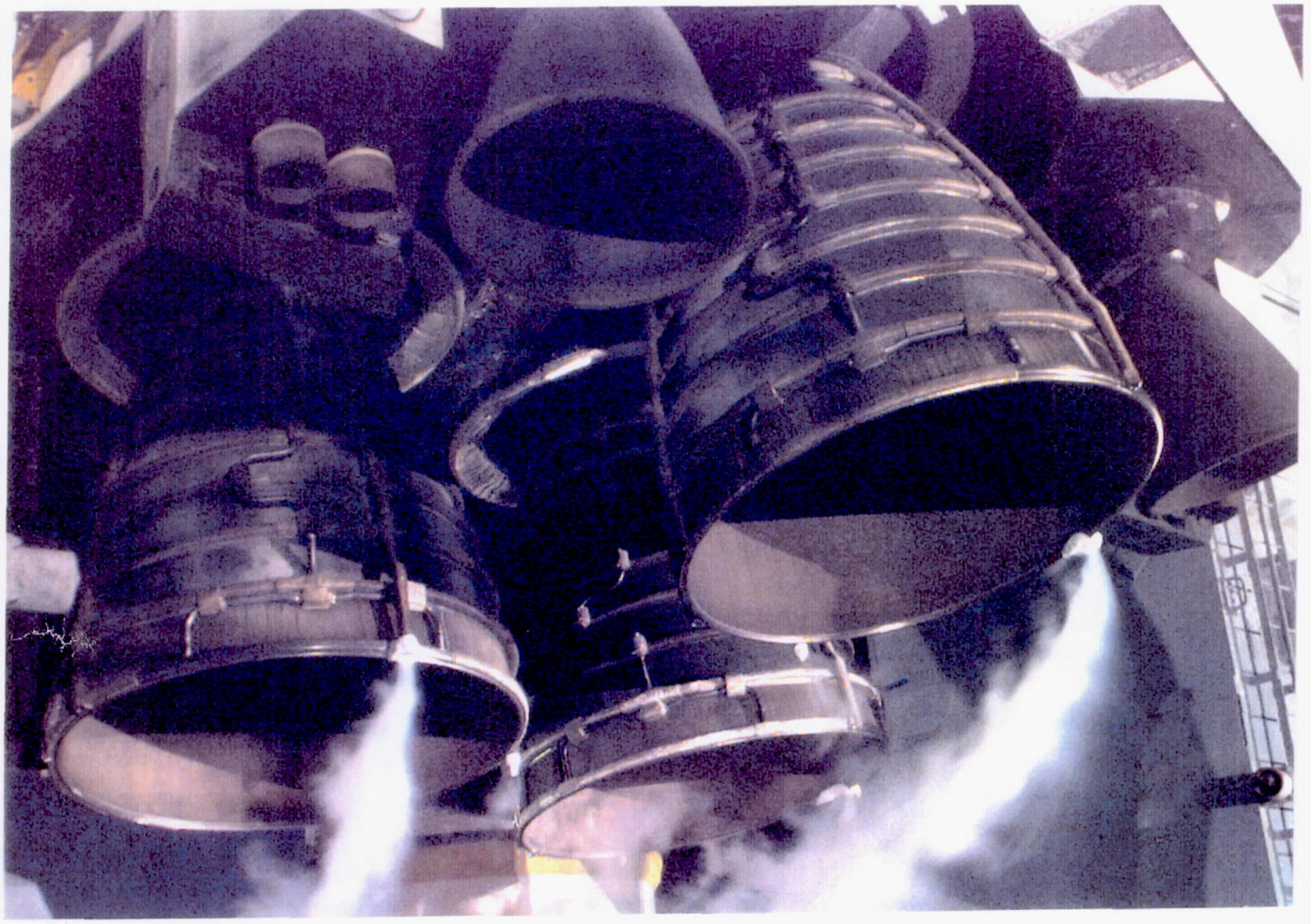


Photo 7: Overall View of SSME's

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, RSS, and Pad A crawlerway/acreage was conducted on 16 September 1996 for two hours starting at Launch + 1 hours.

No flight hardware or TPS materials were found.

South SRB holddown post and shoe erosion was typical. All south HDP shoe shim material was intact. No externally visible evidence of a HDP stud hang-up was found but based on vehicle liftoff lateral acceleration of 0.21g's reported by Rockwell-Downey a stud hand-up did likely occur. A stud hang-up on HDP #3 was later confirmed during post-launch film review. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was typical.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA) and GOX Vent Arm (GVA) appeared undamaged. A minimal amount of topcoat from the External Tank nose cone adhered to the GOX seals (SE louver seal - 1 area approximately 0.75-inches in diameter on the lower RH corner, NW louver seal - 6 to 8 areas all approximately 0.25-inches in diameter on the lower RH corner).

The GH2 vent line had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound. The GUCP leg stabilizer beam showed signs of contact by the latching mechanism. The vent line was latched on the sixth tooth of the latching mechanism

Typical pad damage included:

Several access door panels were blown open and one was found on the pad apron.

A piece of sheet metal (3-feet by 1-foot) with foam adhered to the back side was located on the pad apron.

A cable tray cover on the 155-foot level was torn loose and found on the level grating.

A larger than normal amount of facility foam was found on the north and west side of the pad apron but no single cause could be identified.

Overall, damage to the pad appeared to be minimal.

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No IPR's or IFA's were generated as a result of the film review.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 82 films and videos, which included twenty-six 16mm films, seventeen 35mm films, and thirty-nine videos, were reviewed starting on launch day.

There was no discernible damage to TPS on the ET nose cone, fairing, or footprint area with the exception of some minor topcoat pulled up by the southwest GOX vent seal during hood retraction (OTV 013, 062).

SSME ignition appeared normal. Free burning hydrogen drifted upward towards the OMS pods during start-up. A noticeable amount of free burning hydrogen also drifted northward under the body flap (E-5). Two flares were visible in the SSME plume during engine start-up. (E-2, -3; OTV 051, 063, 070, 071, RSS STI).

SSME ignition caused pieces of ice to fall from the ET/ORB umbilicals. Several pieces of ice contacted the LH2 umbilical cavity sill and were deflected outward. No tile damage was visible. (OTV 009, 063, 064).

Water condensate from the LH2 feedline bellows streamed aft during SSME startup and liftoff (OTV 009).

A piece of fabric, most likely an SRB sound suppression water trough, exited the SSME flame trench at T-0 (E-76).

ET-82 featured the first use of a new black-composite ET intertank access door (OTV 067), which replaced the foam covered door. No anomalies were observed during ignition and liftoff.

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 050, 070, 071).

GUCP disconnect from the ET was nominal. Frost-covered foam, but no damage, was visible on the adjacent stringers after retraction. (OTV 004). Note: the RSS coax cable, the subject of previous engineering observations, is no longer used (E-33).

A stud hang-up occurred on holddown post #3. No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view (E-10)

No stud hang-ups or frangible nut/ordnance debris was observed on any of the other holddown posts.

Small pieces of tile surface coating material were lost from two places on the base heat shield near SSME #3 (E-17), three places near SSME #2 (E-18), and one place on the left RCS stinger aft surface (E-20).

A thin, 4-inch long by 1-inch wide object, similar in appearance to a GSE tile shim, appeared near the forward side of the LO2 T-0 umbilical during disconnect/retraction at 08:54:49.540 UTC (E-17).

At least five pieces of debris, most likely SRB throat plug material, were visible above the north flame trench/SRB plume after T-0 (TV-4A). Eleven pieces were visible in film item E-62.

A flare, caused by RCS paper cover debris, occurred in the SSME plume at T+6 seconds MET (E-57, -224).

Numerous pieces of umbilical ice and RCS paper covers fell aft during ascent, but no contact with flight hardware was observed (E-52, -54).

Numerous pieces of foam from SRB aft skirt aft rings fell alongside the plume during early ascent (TV-21).

Two flares occurred in the SSME plume during ascent at 08:55:14.991 UTC (E-213, -222, -223).

The dark composite ET intertank door exhibited no anomalies during early ascent (E-59).

Body flap movement (amplitude and frequency) appeared similar to previous flights (E-207, -213).

Local flow condensation collars at various points on the vehicle were observed, as expected for the ambient weather conditions (E-212).

Exhaust plume recirculation and ET aft dome charring was typical (E-205). SRB separation appeared normal. Numerous pieces of slag fell from the SRB nozzles and exhaust plume just before, during, and after separation (TV-13; E-207, -208, -212).

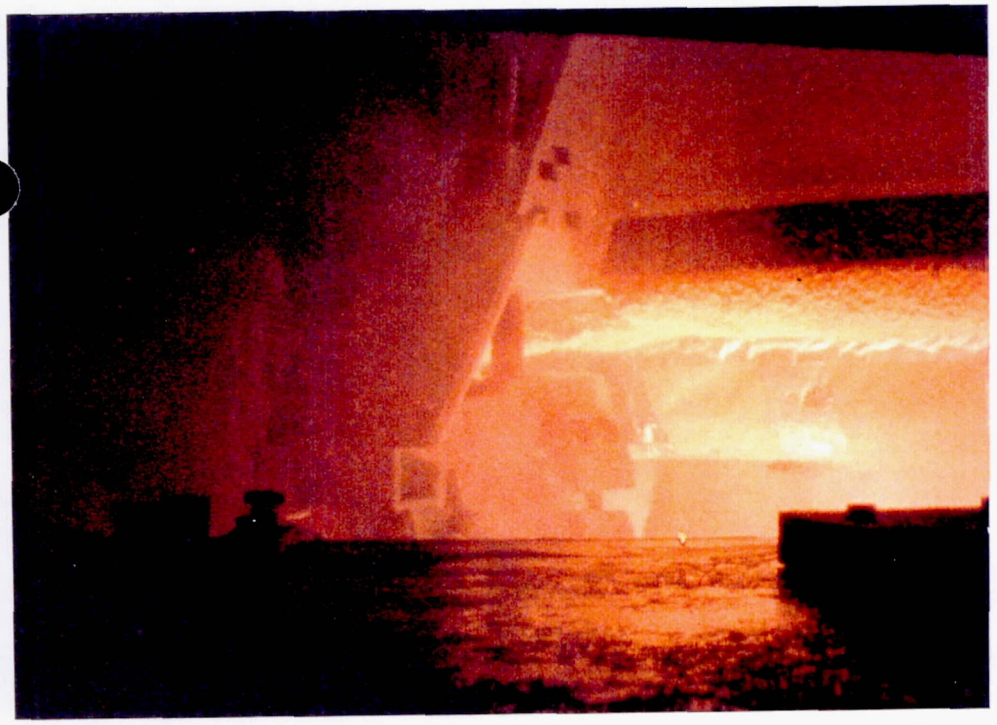


Photo 8: Stud Hang-up

A stud hang-up occurred on holddown post #3. No ordnance fragments or frangible nut pieces fell from the DCS while in the field of view.

5.2 ON-ORBIT FILM AND VIDEO SUMMARY

OV-104 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; 35mm still views. Images of ET separation from the Orbiter were not obtained due to the night launch time. Handheld photography by the flight crew consisted of still 35mm images.

SRB separation from the External Tank appeared nominal.

PDL foam was missing from two places (4-inch and 2-inch diameters, respectively) on the -Y aft fairing splice plate closeout. Depth was estimated to be no greater than 0.5-inches.

Two shallow-appearing divots on the aft dome NCFI near the -Y vertical strut/Xt-2058 ring interface were previously repaired/sanded areas documented prior to launch. Overall, the aft dome exhibited numerous small "popcorn" type divots/erosion and a mottled charred appearance, none of which were considered anomalous.

The absence of topcoat, by design, on the LH2 ET/ORB umbilical cable tray vertical section was evident. No ablator damage was visible in this new configuration.

One 6-inch diameter divot was detected in the LH2 tank-to-intertank flange closeout aft of the -Z RSS antenna outside of the debris zone. A suspect second divot in the LH2 tank flange closeout aft of the +Z RSS antenna could not be confirmed.

5.3 LANDING FILM AND VIDEO SUMMARY

A total of 23 films and videos, which included nine 35mm large format films, two 16mm high speed films, and twelve videos, were reviewed.

While approaching the HAC, multiple vapor puffs aft of the Orbiter were most likely RCS firings, but could have been fluid dumps.

The landing gear extended properly. The infrared scanners showed no debris falling from the Orbiter during final approach. Left and right main landing gear touchdown was virtually simultaneous at approximately 800 feet from the runway threshold. The Orbiter stayed close to the runway centerline during rollout.

Drag chute deployment appeared nominal. The chute was blown slightly westward by the crosswind.

Touchdown of the nose landing gear was smooth. Rollout and wheel stop were uneventful.

No significant TPS damage was visible in the films.

Photo 9: ET After Separation

The aft dome exhibited numerous small "popcorn" type divots/erosion and a mottled charred appearance, none of which were considered anomalous.

Photo 10: ET After Separation

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The BI-083 Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 18 September 1996. From a debris standpoint, both SRB's were in excellent condition.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS. The number of debonds over fasteners (17) was less than average (Figure 1). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the severance ring.

A 7/16 inch combination wrench was found inside the SRB forward skirt. Except for the vendor name (Armstrong-USA), no other markings were present on the wrench. A tether was not attached to the wrench. An investigation team concluded that the wrench was most probably left in the forward skirt during manufacturing activities and was not discovered during the final turnover inspection, prior to delivery to SFOC or during the final close-out inspection, at the Pad, performed by SFOC. Recommendations were made to enhance inspection procedures at all USBI and SFOC SRB inspection points and to improve the USBI tool control system at the manufacturing facility.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. Water impact deformed the upper strut fairing. The ETA ring, IEA, and IEA covers appeared undamaged. Several stiffener rings had been damaged by water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. Instafoam was missing and the substrate was exposed on the aft skirt aft ring from HDP #2 to the HPU exhaust ducts. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during early ascent.

A stud hang-up occurred on HDP #3 and the stud hole was broached. The stud hang-up was confirmed in the launch film review of film item E-10.

All HDP Debris Containment Systems (DCS) plungers were seated and appeared to have functioned normally.

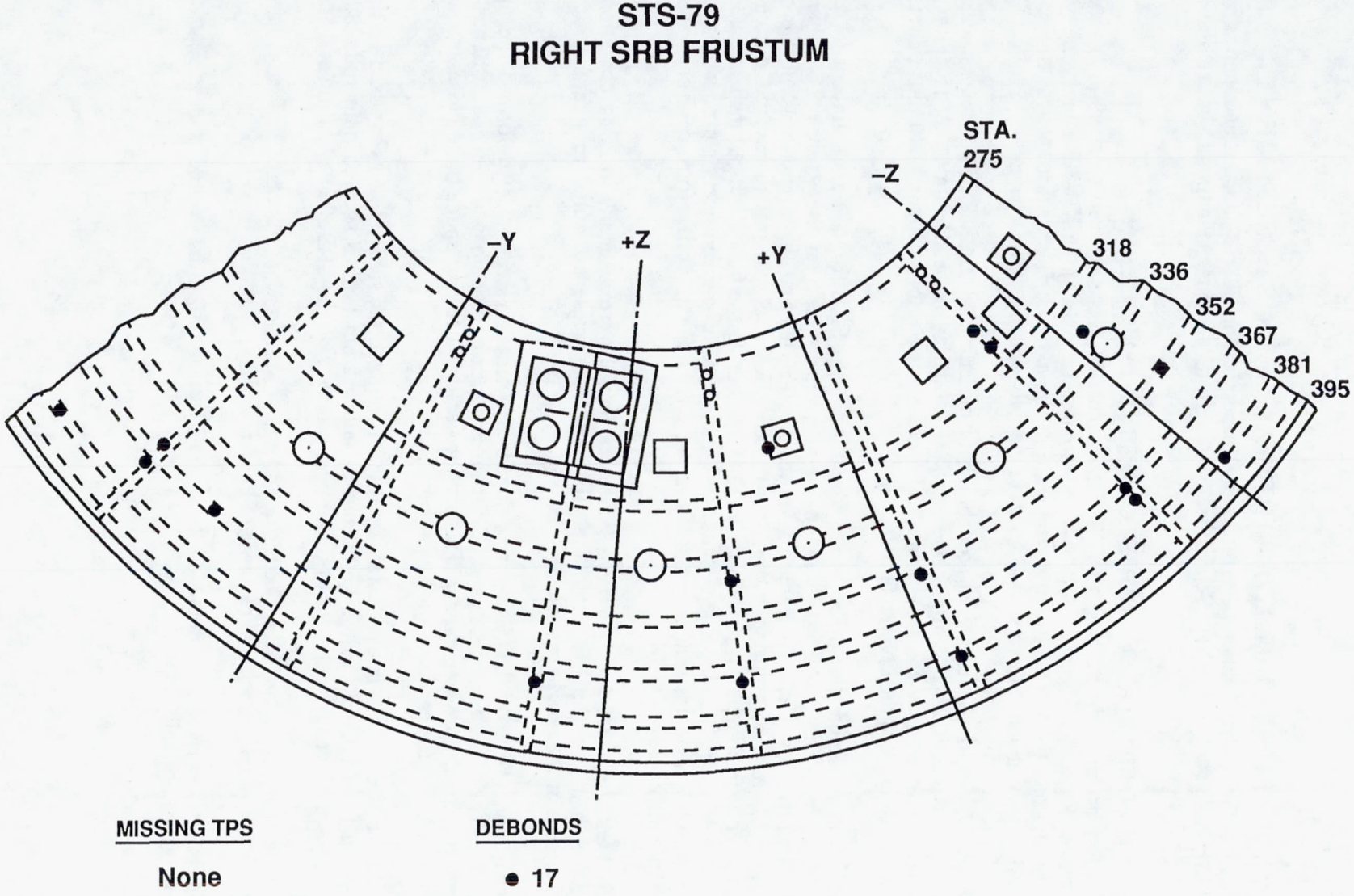


Figure 1: RH SRB Frustum

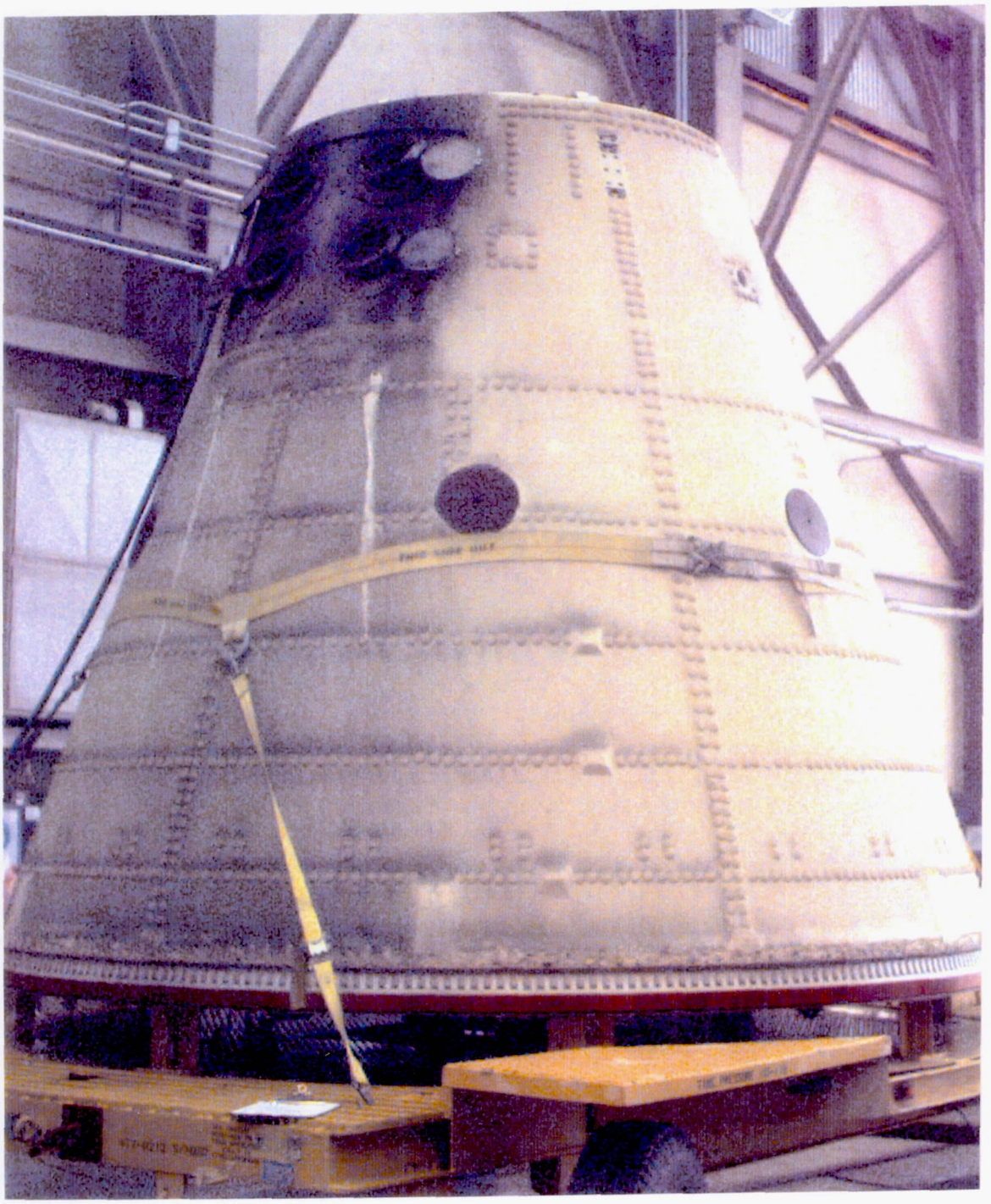


Photo 11: RH Frustum

The RH frustum was missing no TPS. The number of debonds over fasteners (17) was less than average. Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The BSM aero heat shield covers had locked in the fully opened position.

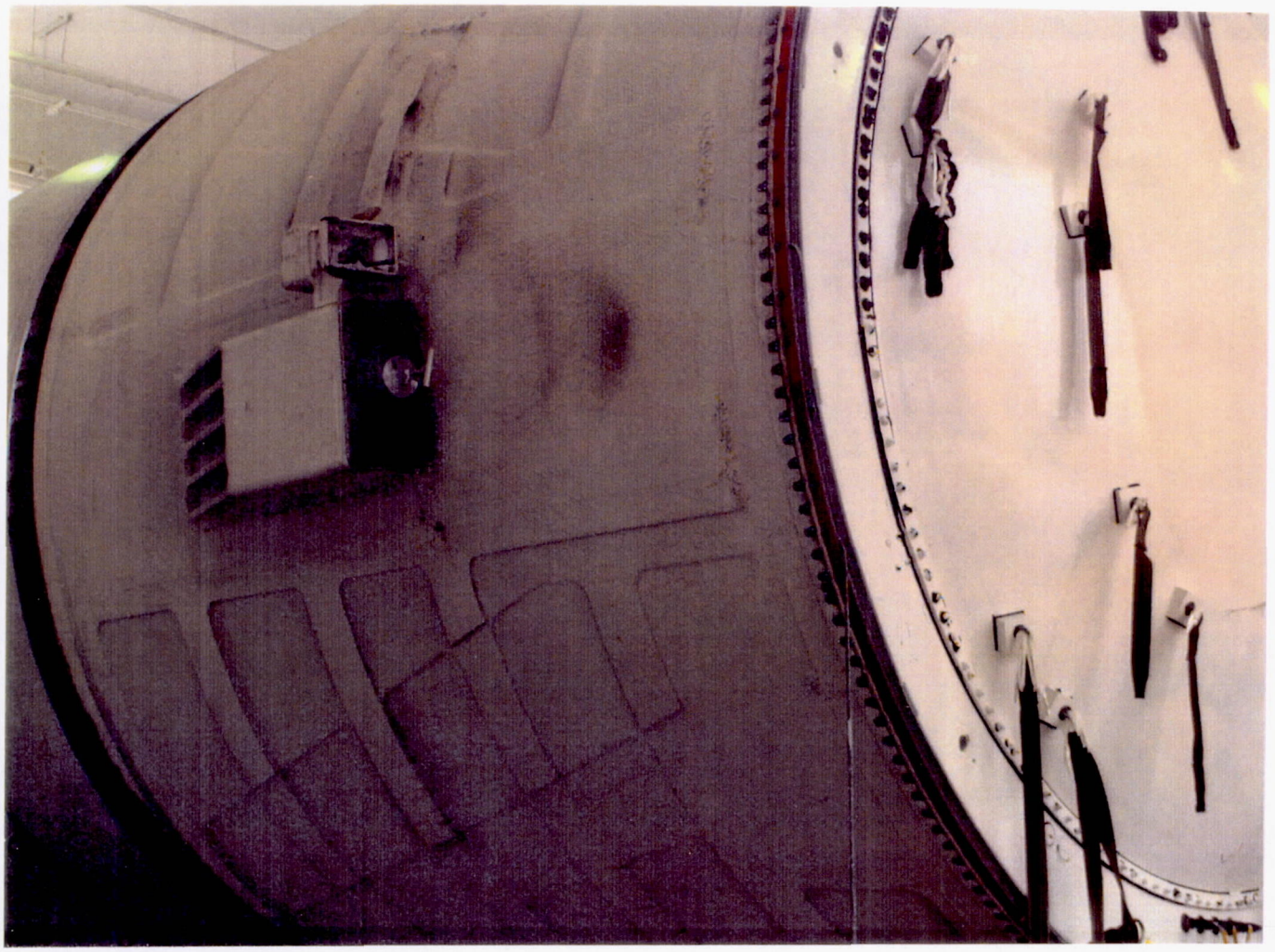


Photo 12: RH Forward Skirt

The RH forward skirt exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips were missing from the severance ring.

Photo 13: RH Aft Booster/Aft Skirt

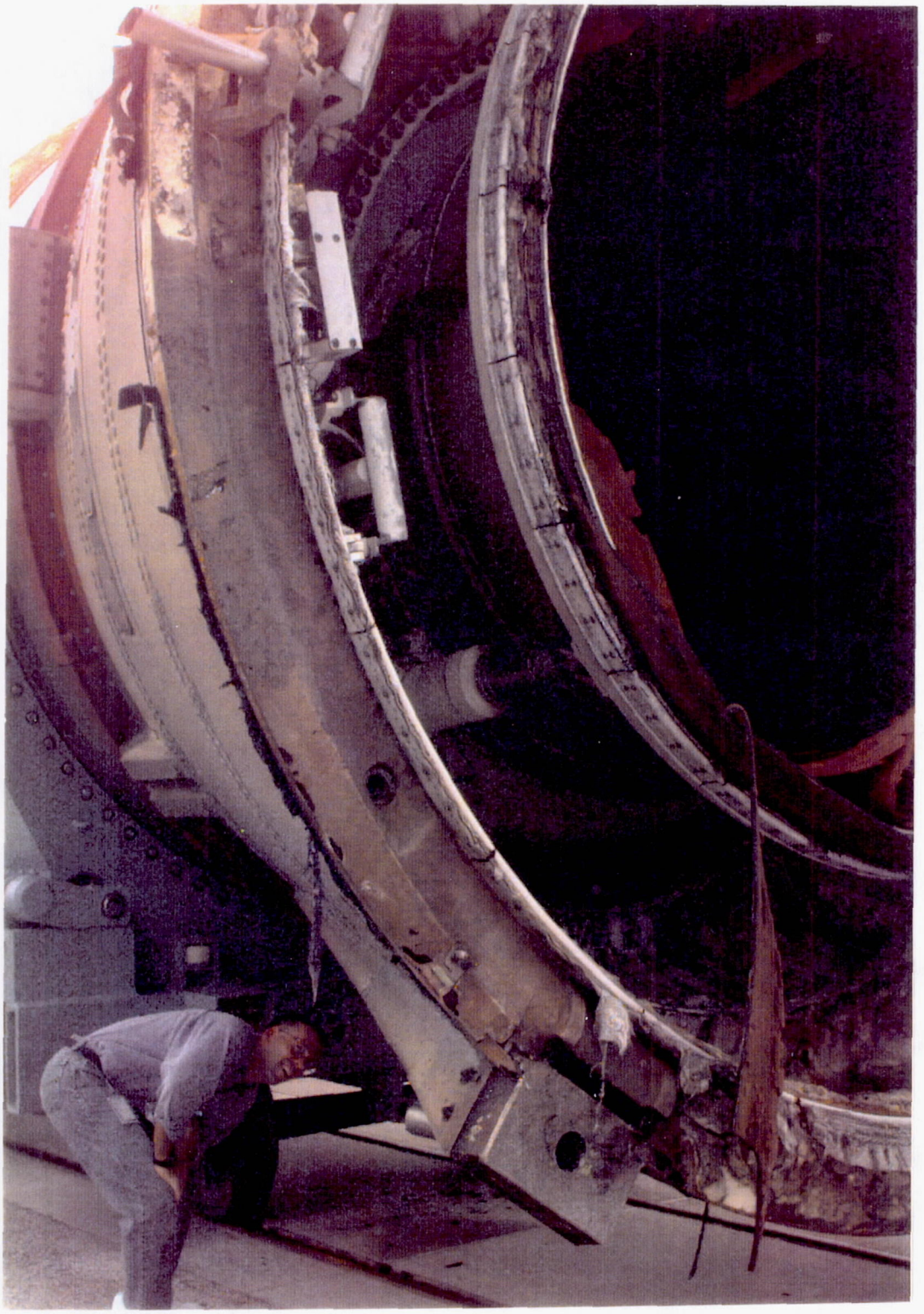


Photo 14: Aft Skirt Aft Ring Missing Foam

Instafoam was missing and the substrate was exposed on the aft skirt aft ring from HDP #2 to the HPU exhaust ducts. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during ascent.

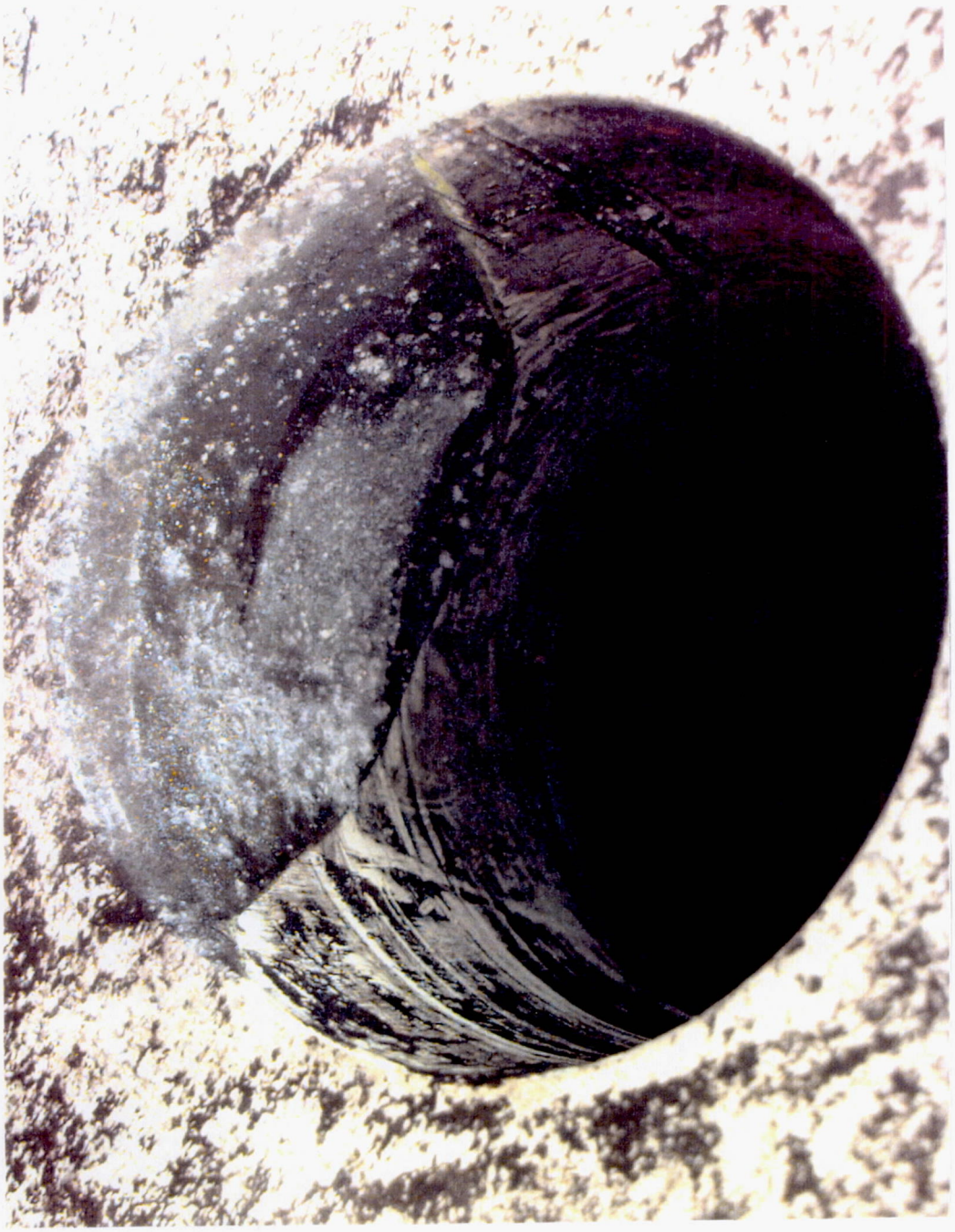


Photo 15: HDP #3 Stud Hole Broaching

A stud hang-up occurred on HDP #3 and the stud hole was broached. The stud hang-up was confirmed in the launch film review.

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (5) was less than average (Figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The two left BSM aero heat shield covers had been bent by parachute entanglement; the lower right cover was locked in the fully open position, and the forward right cover was missing. Laboratory testing attributed the loss of the cover to parachute riser entanglement or water impact.

The LH forward skirt exhibited no TPS debonds. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips from the frustum severance ring were missing or damaged.

The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ETA ring, IEA, and IEA covers appeared undamaged. The foam ramp adjacent to the systems tunnel was debonded from the ETA ring. Four indentations in the forward face of the ETA ring were most likely caused by debris impacts. However, no foreign objects were visible in the indentations. Several stiffener rings had been damaged by water impact. The forward stiffener ring had separated from the aft booster from 190 to 240 degrees. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Aft skirt MSA-2 was intact. More than usual amounts of foam were missing from the aft skirt aft ring. Launch films showed numerous light colored particles, believed to be pieces of foam, falling along side the SRB plumes during early ascent.

All HDP Debris Containment Systems (DCS) were seated and appeared to have functioned normally.

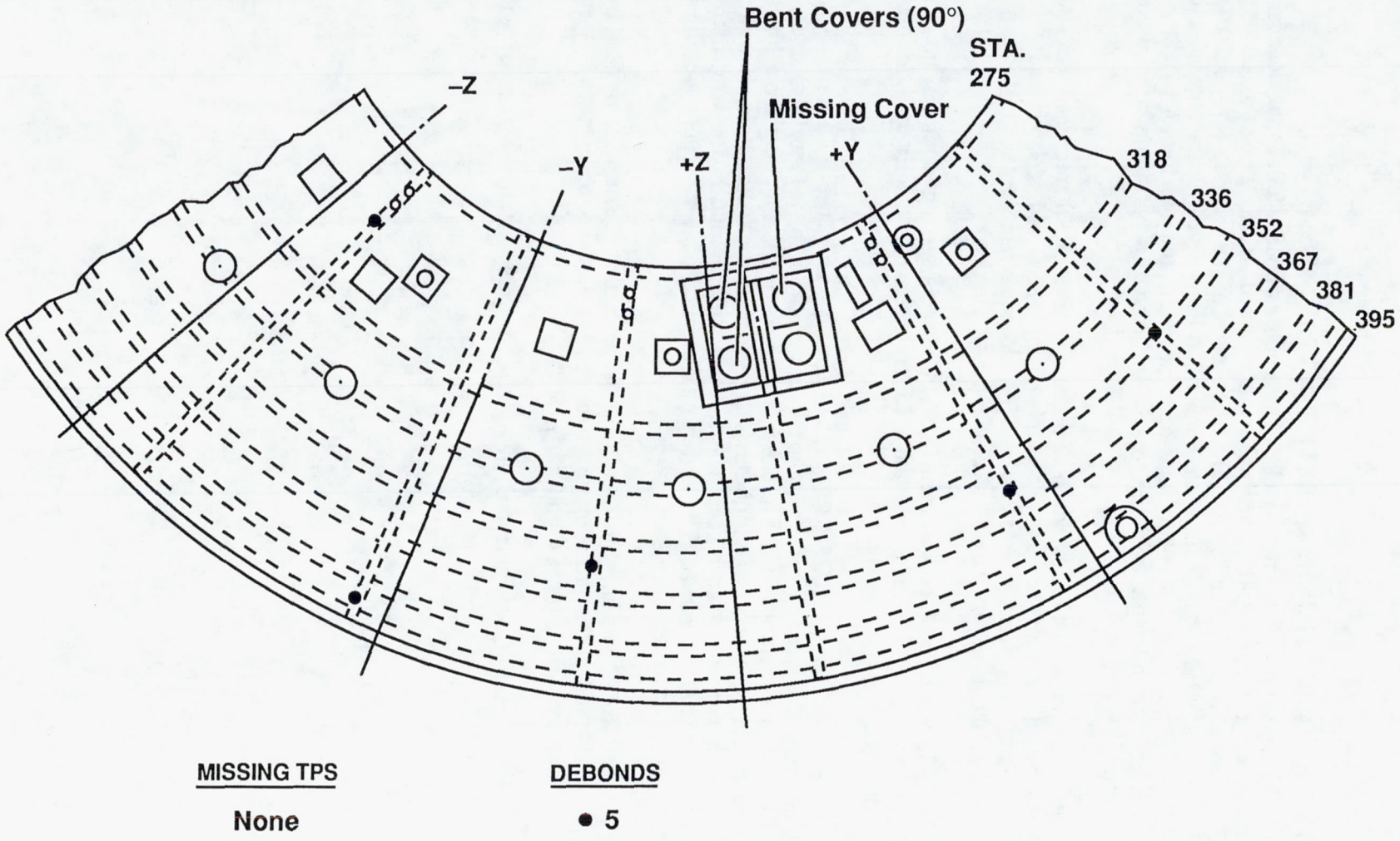


Figure 2: LH SRB Frustum

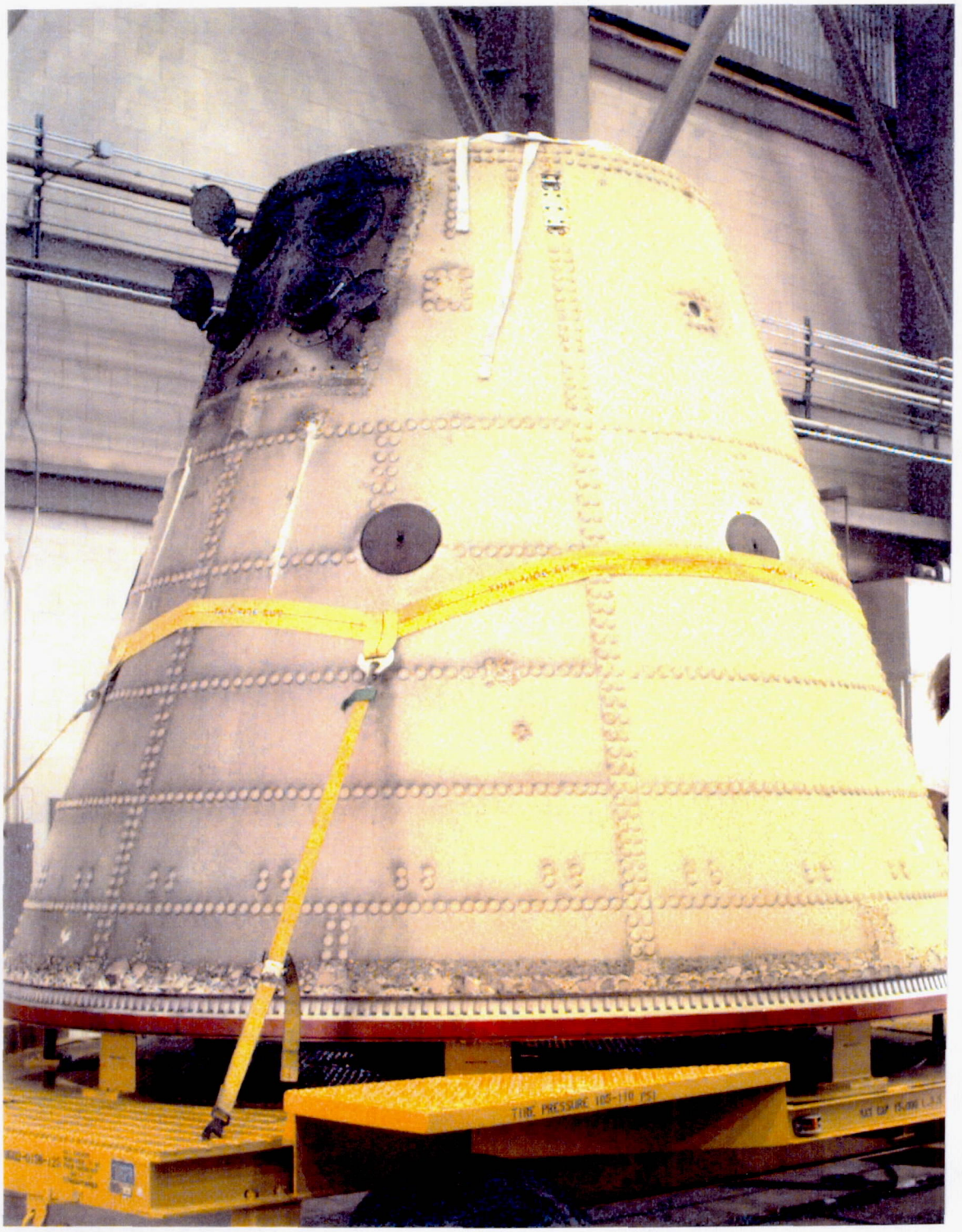


Photo 16: LH Frustum

The LH frustum was missing no TPS. The number of MSA-2 debonds over fasteners (5) was less than average (Figure 2). Hypalon paint was blistered/missing along the XB-395 ring frame where BTA closeouts had been applied. However, most of the exposed BTA substrate was not sooted. The two left BSM aero heat shield covers had been bent by parachute entanglement; the lower right cover was locked in the fully open position, and the forward right cover was missing.

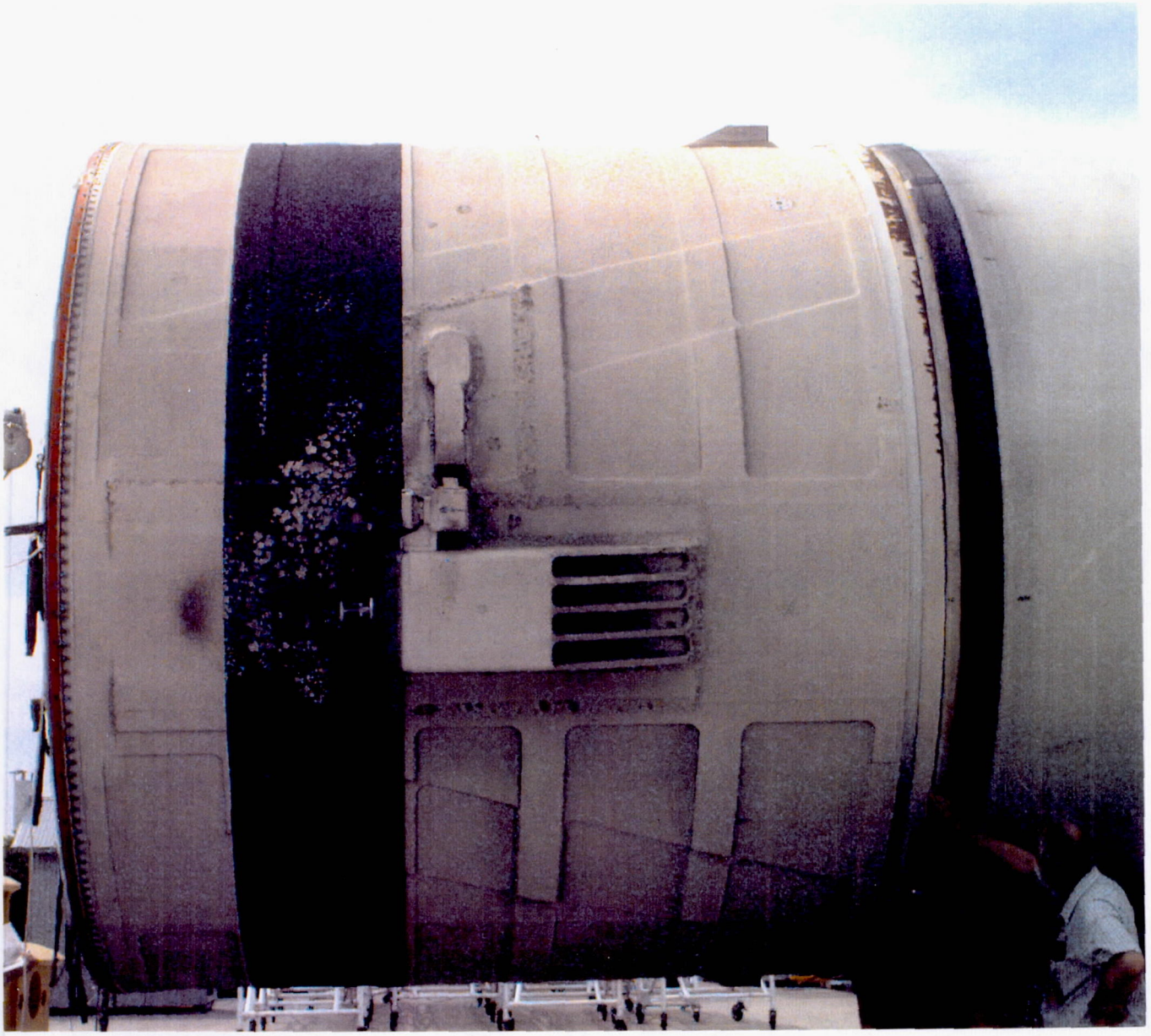


Photo 17: LH Forward Skirt

The LH forward skirt exhibited no TPS debonds. Both RSS antennae covers/phenolic base plates were intact though some of the phenolic layers had delaminated. Hypalon paint was blistered/missing over the areas where BTA closeouts had been applied. No pins or retainer clips from the frustum severance ring were missing or damaged.

Photo 18: LH Aft Booster/ Aft Skirt

Several stiffener rings had been damaged by water impact. The forward stiffener ring had separated from the aft booster from 190 to 240 degrees.

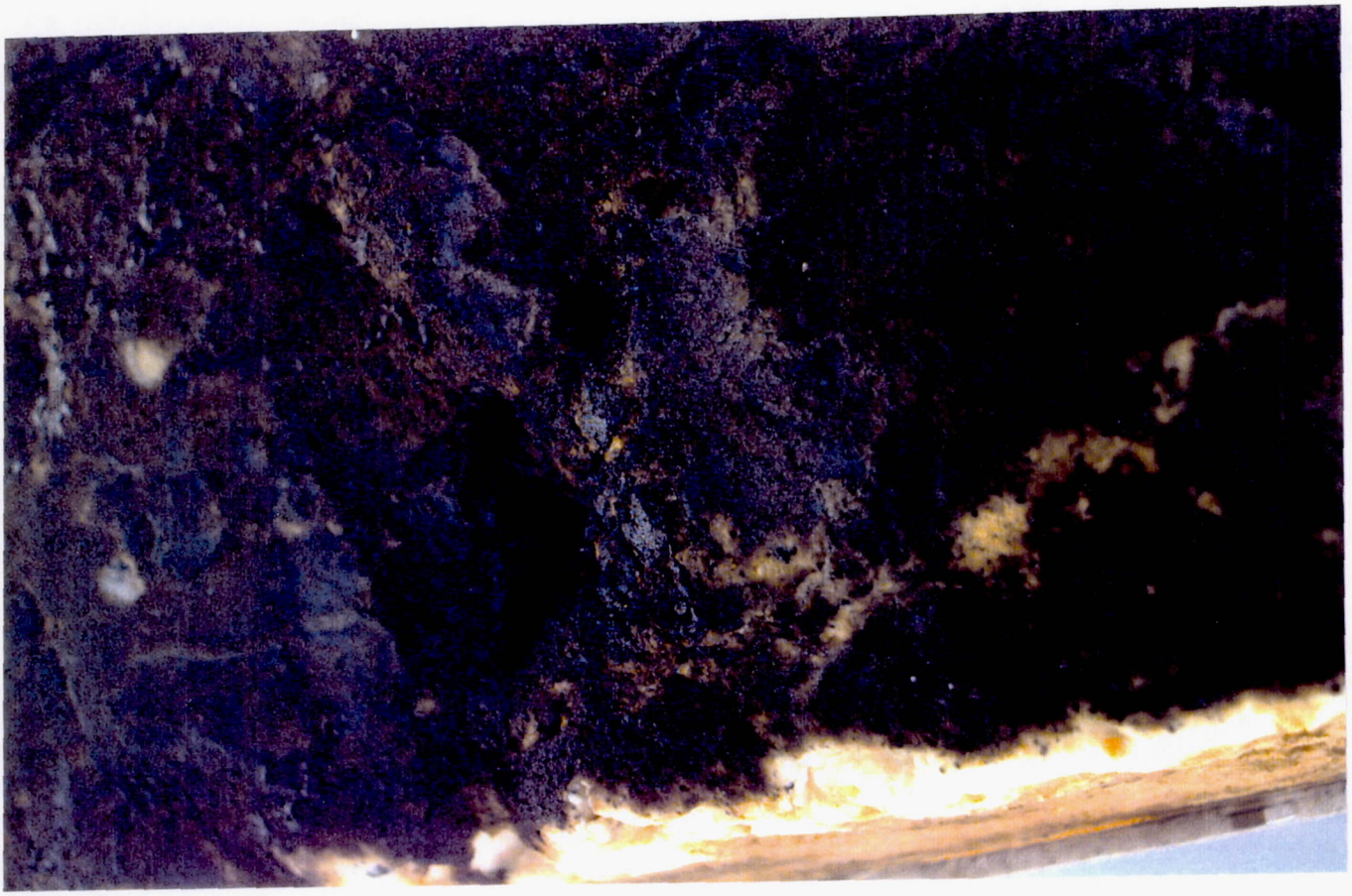


Photo 19: ETA Ring Debris Impacts

Four indentations, one of which is shown in the above photograph, in the forward face of the ETA ring were most likely caused by debris impacts. However, no foreign objects were visible in the indentations.

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing inspection of OV-104 Atlantis was conducted 26-27 September 1996 at the Kennedy Space Center on SLF runway 15 and in the Orbiter Processing Facility bay #3. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 103 hits, of which 11 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 63 previous missions of similar configuration (excluding missions STS-23, 24, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger were less than average (reference attached figures).

The following table breaks down the STS-79 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	8	65
Upper surface	2	20
Right side	0	3
Left side	1	4
Right OMS Pod	0	7
Left OMS Pod	0	4
TOTALS	11	103

The largest lower surface tile damage site was located outboard and aft of the right main landing gear door and measured 6.0-inches long by 1.0-inch wide by 0.125-inch maximum depth. The damage was most likely caused by an ice impact from the ET LO2 feedline bellows and support brackets.

Tile damage sites aft of the LH2 and LO2 ET/ORB umbilicals were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream.

One gap filler inboard of the right main landing gear door protruded from lower surface tiles.

No tile damage from micrometeorites or on-orbit debris was identified during this inspection.

The tires and brakes were reported to be in average condition for a landing on the KSC concrete runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH2 recirculation line disconnect.

All three SSME Dome Mounted Heat Shield (DMHS) closeout blankets were in excellent condition.

No ice adhered to the payload bay door. No unusual tile damage was observed on the leading edges of the OMS pods. However, two tiles on the leading edge of the vertical stabilizer were damaged; the damage measured 3.5 inches by 1.5 inches by 0.25 inches.

A white tile (V070-39143-080-008507) above window #1 had a piece approximately 2.5-inches by 1.5-inches by 1.0-inch missing from the forward-most corner of the tile. Filler bar was visible and a part of the Strain Isolation Pad (SIP) appeared to be missing.

Hazing and streaking of Orbiter windows #2, #3, #4 and #5 was typical. Window #4 had 2 splatter marks which were most likely caused by impacts from FRCS RTV. Damage sites on the window perimeter tiles (3 hits on window #2 and 4 hits on #3) were most likely a combination of some new hits and old repair material flaking off.

The post landing walkdown of Runway 15 was performed immediately after landing. No debris concerns were identified. All drag chute hardware was recovered and appeared to have functioned normally.

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger were less than average when compared to previous missions.

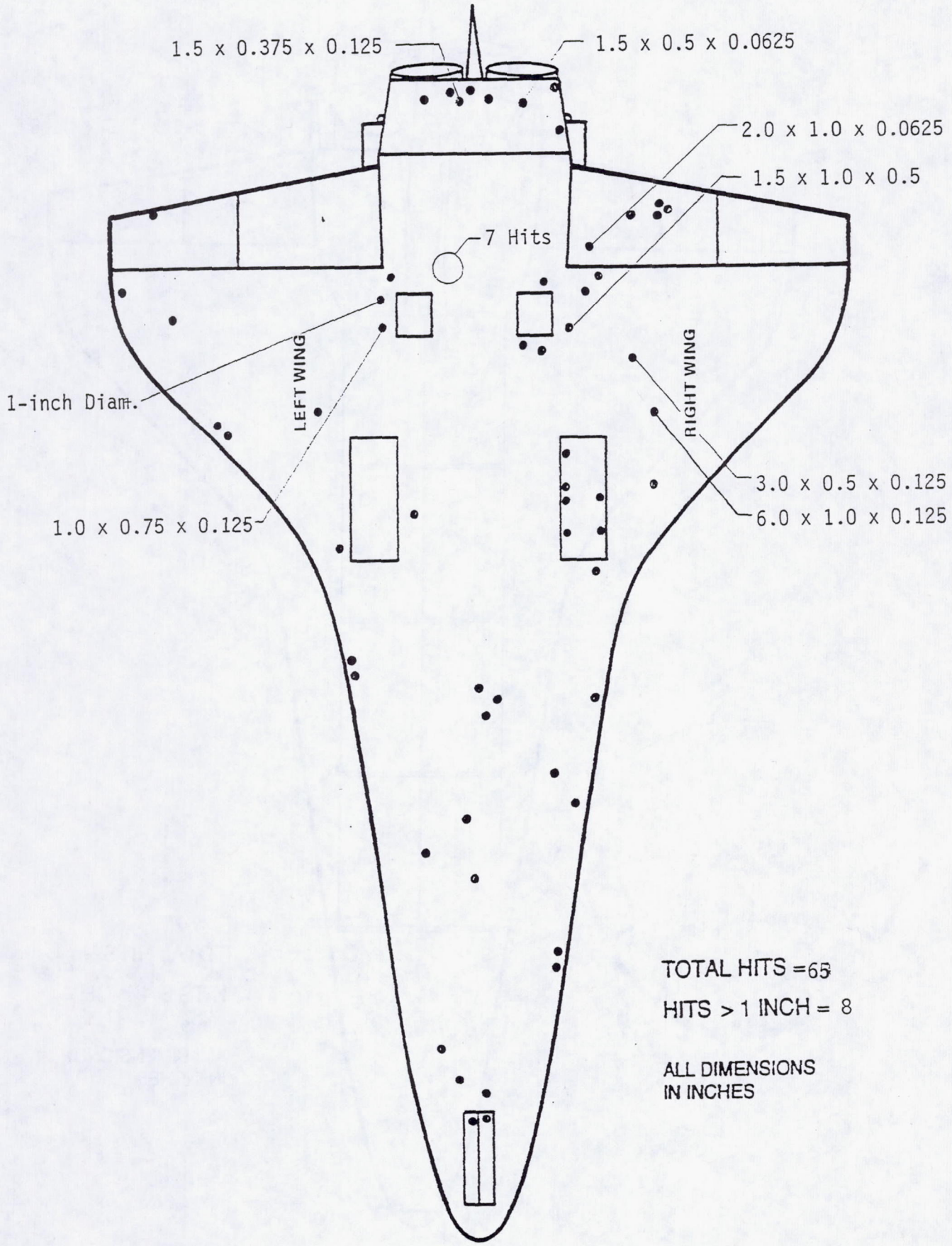


Figure 3: Orbiter Lower Surface Debris Map

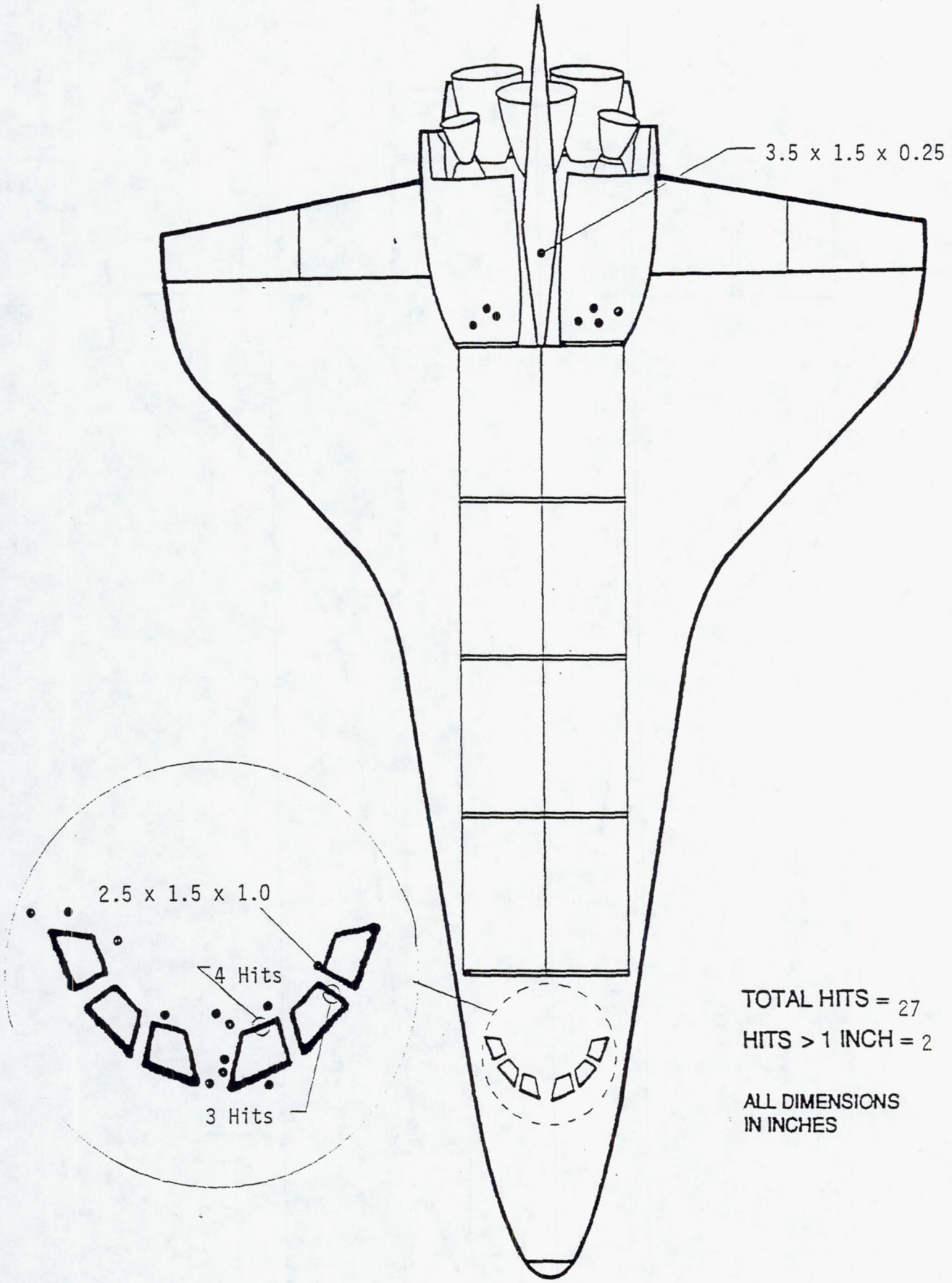
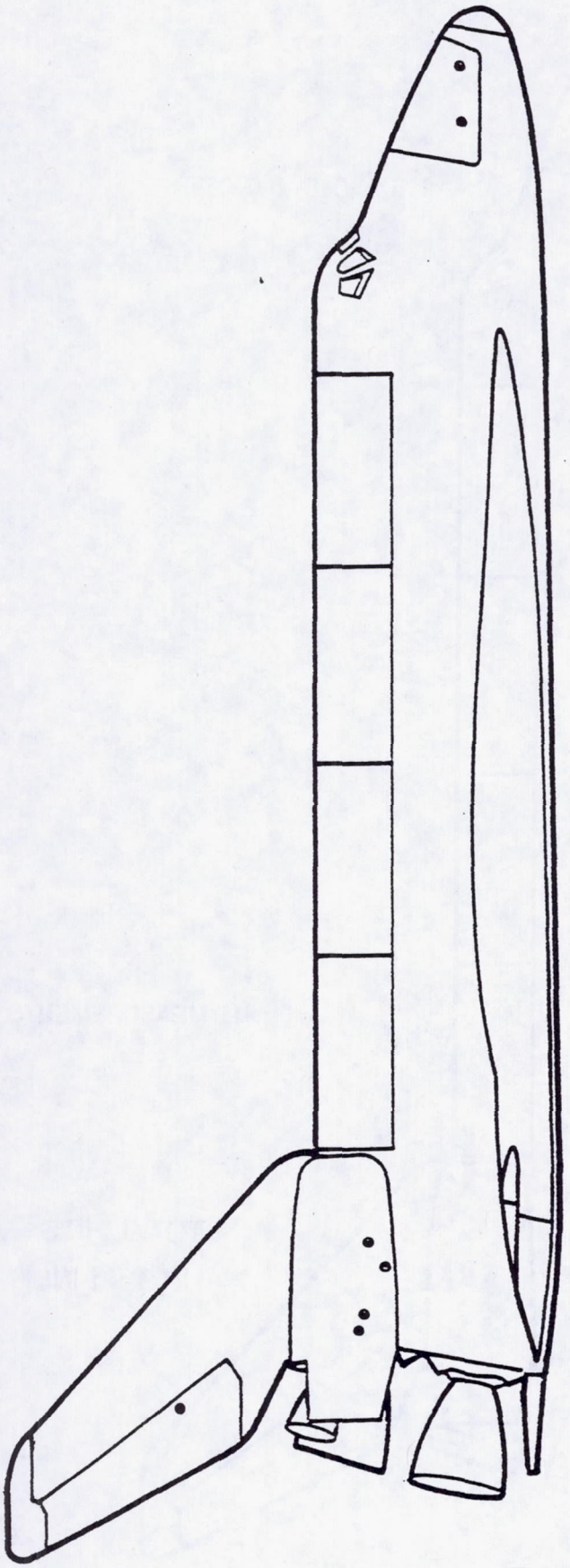


Figure 4: Orbiter Upper Surface Debris Map



TOTAL HITS = 7

HITS > 1 INCH = 0

Figure 5: Orbiter Right Side Debris Map

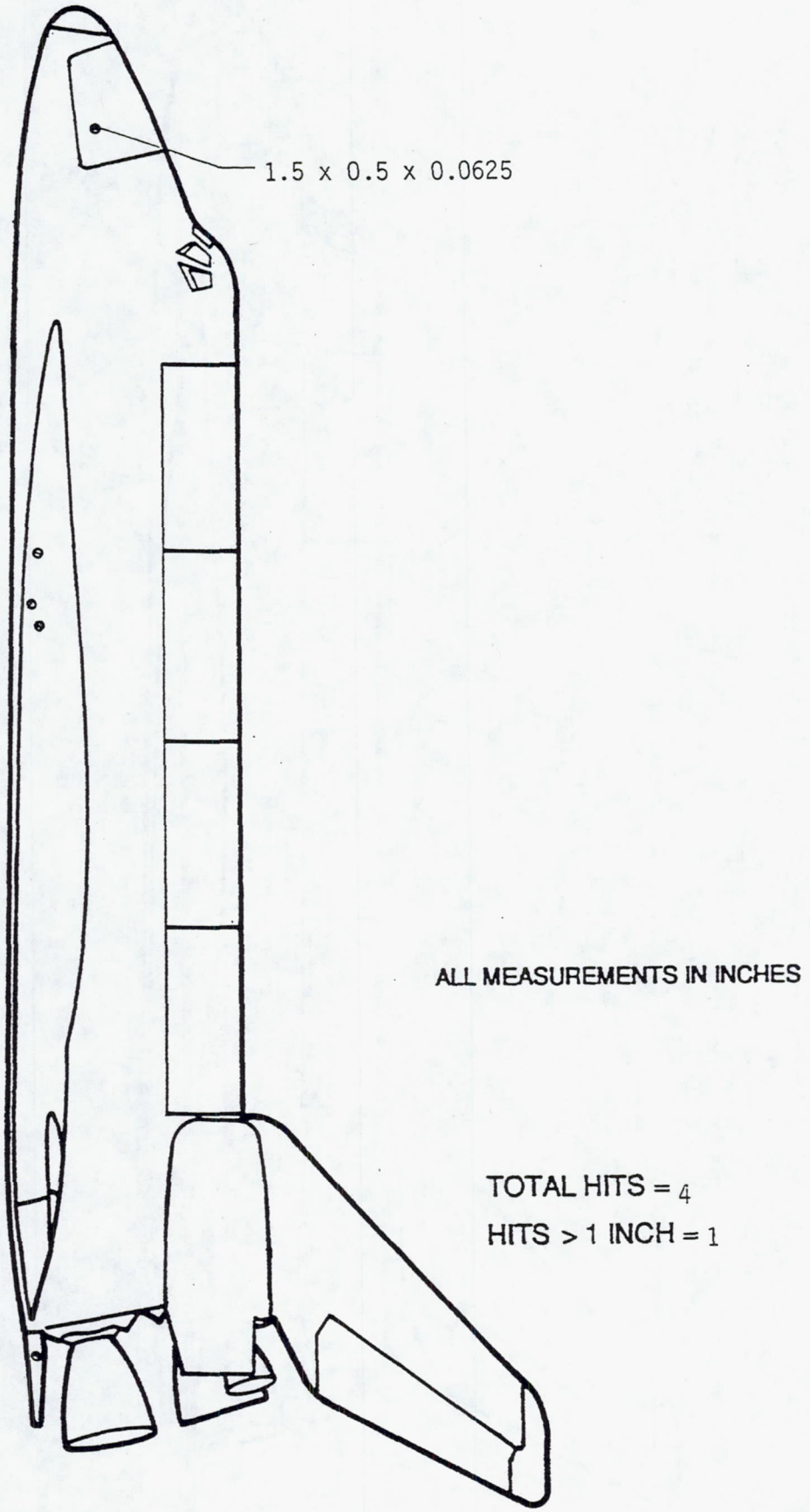


Figure 6: Orbiter Left Side Debris Map

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	21	89	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156

	LOWER SURFACE		ENTIRE SURFACE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-55	10	128	13	140
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
STS-63	7	84	14	125
STS-67	11	47	13	76
STS-71	24	149	25	164
STS-70	5	81	9	127
STS-69	22	175	27	198
STS-73	17	102	26	147
STS-74	17	78	21	116
STS-72	3	23	6	55
STS-75	11	55	17	96
STS-76	5	32	15	69
STS-77	15	48	17	81
STS-78	5	35	12	85
AVERAGE	13.8	87.8	20.5	127.7
SIGMA	7.3	44.3	9.7	54.1
STS-79	8	65	11	103

MISSIONS STS-23,24,25,26,26R,27R,30R,AND42R ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

Figure 7: Orbiter Post Flight Debris Damage Summary

Photo 20: Orbiter Left Side Overall View

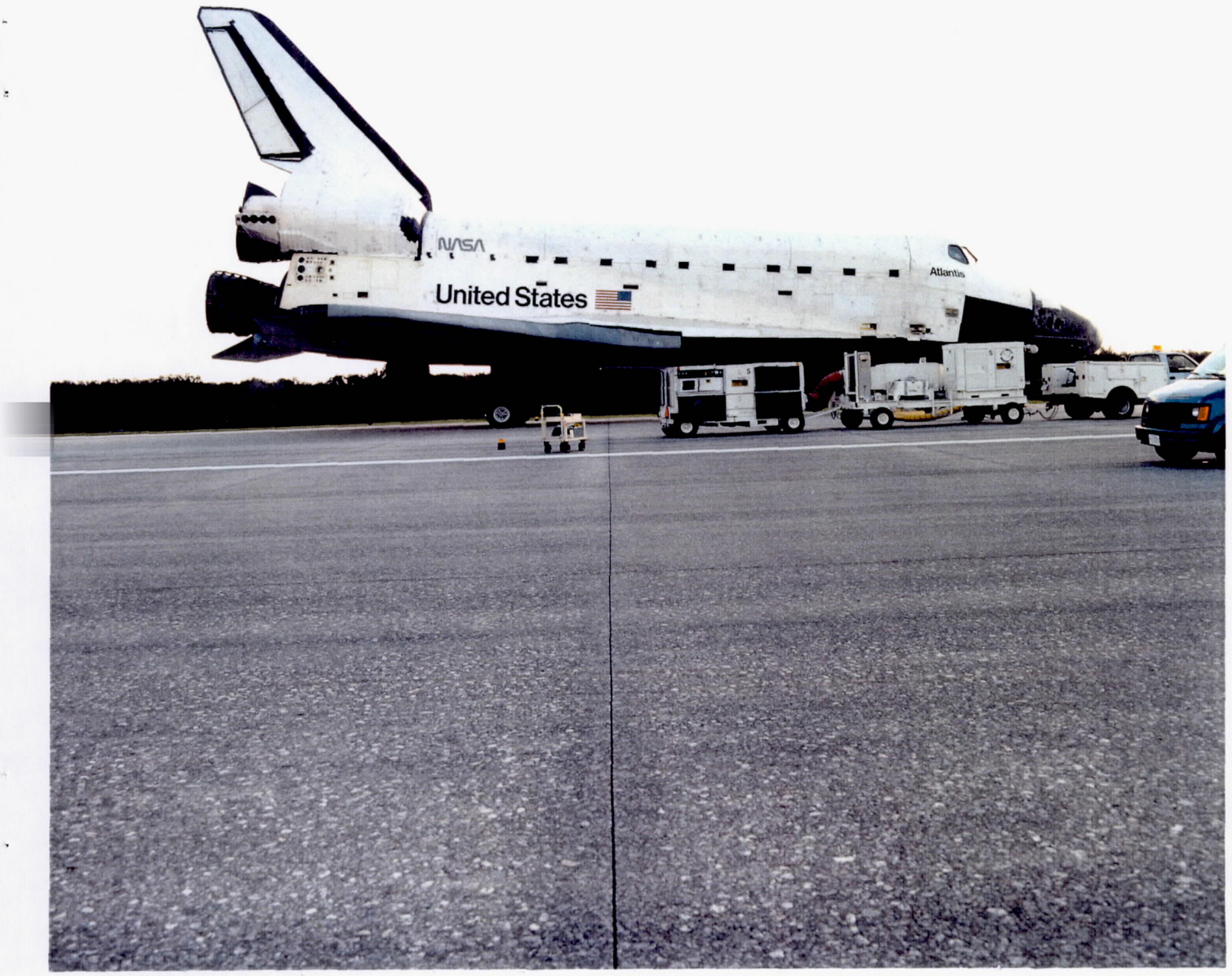


Photo 21: Orbiter Right Side Overall View

Photo 22: Base Heat Shield/SSME's

All three SSME Dome Mounted Heat Shield (DMHS) Blankets were in excellent condition.

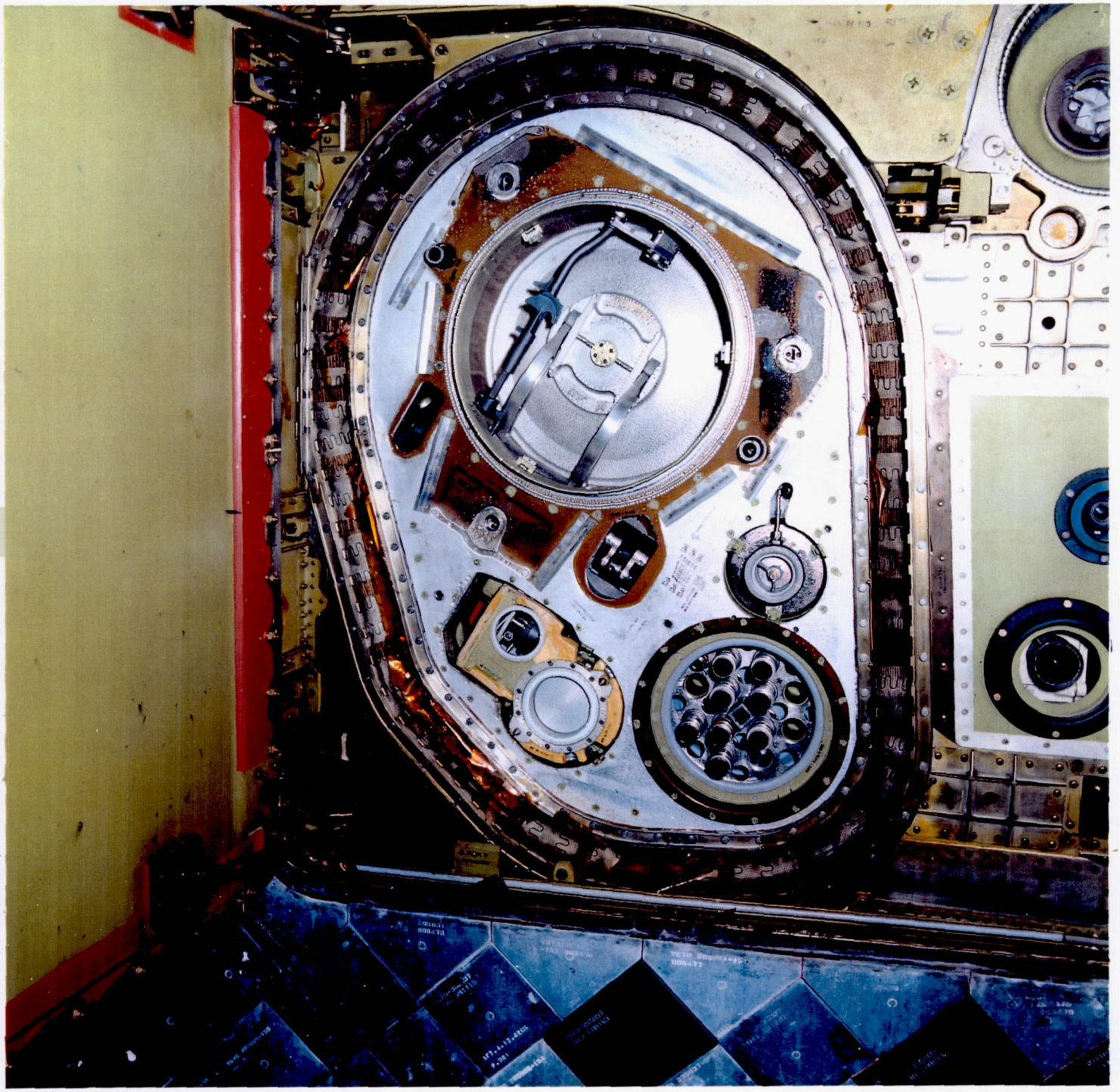


Photo 23: LH2 ET/ORB Umbilical

Photo 24: LO2 ET/ORB Umbilical

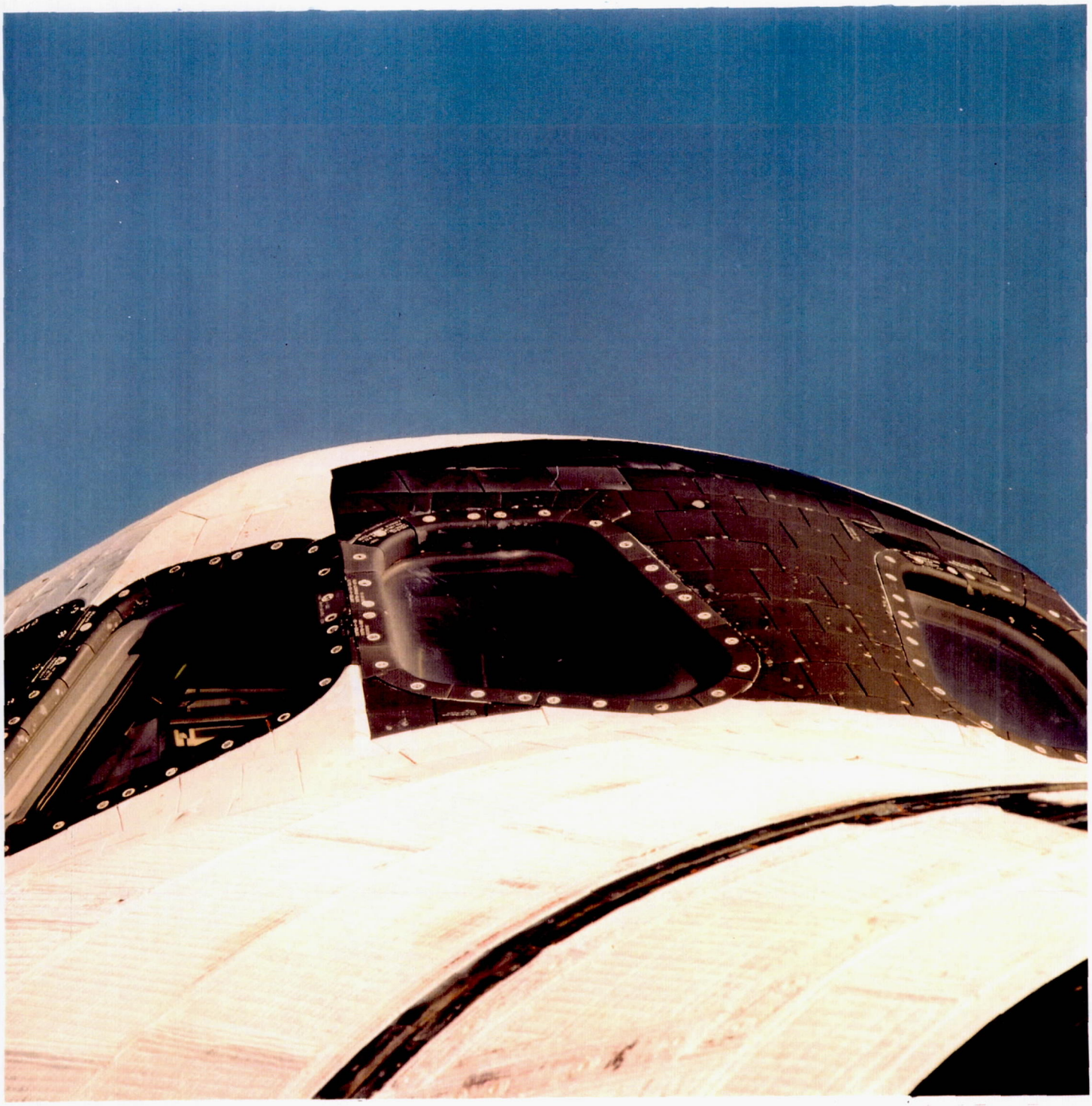


Photo 25: Orbiter Windows 4-6

Hazing and streaking of Orbiter windows #4 and #5 was typical. Window #4 had 2 splatter marks which were most likely caused by impacts from FRCS RTV.

8.0 DEBRIS SAMPLE LAB REPORTS

In an effort to reduce report production costs, the debris sample analysis section will only be printed in the event of an anomalous finding.

APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

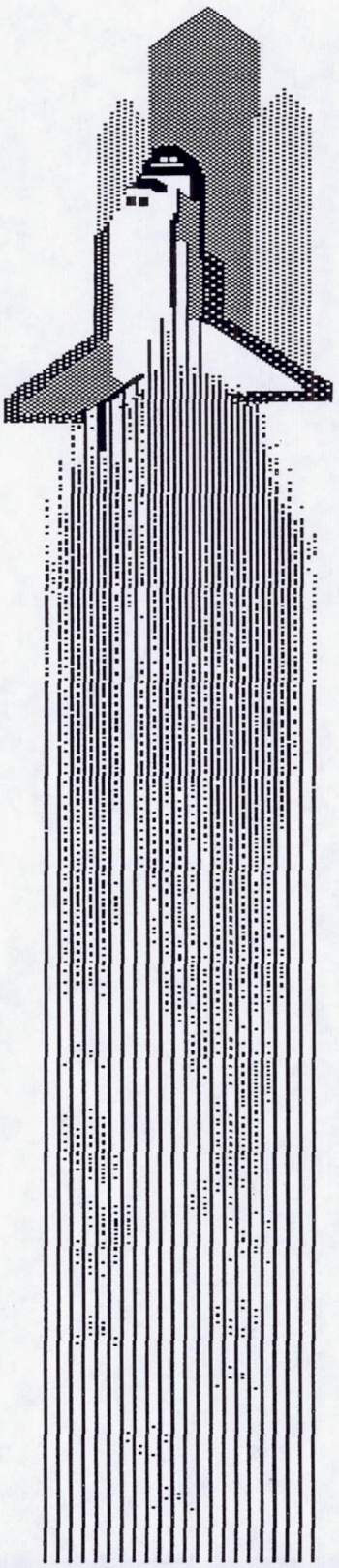
Space Shuttle

Earth Science Branch

Image Science and
Analysis Group

STS-79 Summary of Significant Events

October 25, 1996



Space Shuttle Image Science and Analysis Group

STS-79 Summary of Significant Events

Project Work Order - SN-5LA

Approved By

Lockheed Martin

10/28/96
Robert Meltzer, Project Analyst
Image Science and Analysis Group

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Lockheed Martin Engineering and Sciences Company
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Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

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1. STS-79 (OV-104): FILM / VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

The STS-79 launch of Columbia (OV-104) from pad A occurred on Monday, September 16, 1996, (day 260) 08:54:49.001 Coordinated Universal Time (UTC) as seen on camera E9. Solid Rocket Booster (SRB) separation occurred at 08:56:51.039 UTC as seen on camera ET204.

On launch day, 24 of 24 expected videos were received and screened. Following launch day, 40 films were screened. Camera films E4, E11, and E60 were not received. A bolt hang-up was seen at the RSRB holddown post M-3 at liftoff.

Detailed Test Objective 312, was performed using the Orbiter umbilical well cameras (method 1). Photography of the LSRB separation was acquired. Images of the external tank (ET) umbilical separation were unusable due to darkness. Handheld photography of the ET was acquired using the Nikon F4 with the 300 mm lens and 2x converter (method 3).

1.1.2 Landing

Columbia landed on runway 15 at the KSC Shuttle Landing Facility on September 26, 1996. Eleven videos were received and screened. No potential anomalies were observed during landing.

No major anomalies were noted in the approach, landing, or roll-out video and film views screened. The drag chute deployment appeared normal.

1.2 TIMING ACTIVITIES

Launch:

The time codes from videos and films were used to identify specific events during the initial screening process.

Video cameras: ET204, ET207, ET208, ET212, ET213, KTV2, KTV4A, KTV5, KTV7A, KTV11, KTV13, KTV21A, OTV009, OTV041, OTV048, OTV049, OTV050, OTV051, OTV054, OTV060, OTV061, OTV063, OTV070, and OTV071 had IRIG timing.

Film cameras: E205, E207, E208, E212, E213, E220, and E223 had IRIG timing. E1, E2, E3, E5, E7, E8, E9, E10, E12, E13, E14, E15, E16, E17, E18, E19, E20, E31, E33, E34, E36, E40, E41, E52, E54, E57, E59, E62, E63, E76, E77, E222, and E224 had in-frame alphanumeric timing.

Landing:

Video cameras: Eleven videos were screened on landing day; EL17IR, EL18IR, KTV5L, KTV6L, KTV11L, KTV12L, KTV13L, KTV15L, KTV33L, SLF North, and SLF South had IRIG timing.

Film cameras: The eleven film cameras of landing (EL1, EL2, EL4, EL6, EL7, EL9, EL10, EL12, EL15, EL30, and EL31) had in-frame alphanumeric timing.

The landing and drag chute event times are provided in Table 1.2.

Event Description	Time (UTC)	Camera
Landing Gear - Doors Opened	270:12:12:58.459	KTV15L
Right Main Wheel Touchdown	270:12:13:12.993	SLF North
Left Main Wheel Touchdown	270:12:13:13.026	SLF North
Drag Chute Initiation	270:12:13:21.368	SLF North
Pilot Chute at Full Inflation	270:12:13:22.237	KTV33L
Bag Release	270:12:13:22.871	KTV33L
Drag Chute Inflation in Reefed Configuration	270:12:13:23.872	KTV33L
Drag Chute Inflation in Disreefed Configuration	270:12:13:27.242	KTV33L
Nose Wheel Touchdown	270:12:13:28.544	KTV33L
Drag Chute Release	270:12:13:56.805	KTV33L
Wheel Stop	270:12:14:31.564	KTV6L

Table 1.2 Landing Video Timing Events

2. SUMMARY OF SIGNIFICANT EVENTS

2.1 DEBRIS

None of the debris seen on the STS-79 engineering films and videos appeared to contact the vehicle. No follow-up action was requested.

2.1.1 Debris Near the Time of SSME Ignition

As on previous missions, multiple pieces of debris were seen near the time of SSME ignition. Most of the debris were umbilical ice and RCS paper.

2.1.1.1 Debris Aft of the SSMEs During SSME Ignition
(Camera: OTV171)

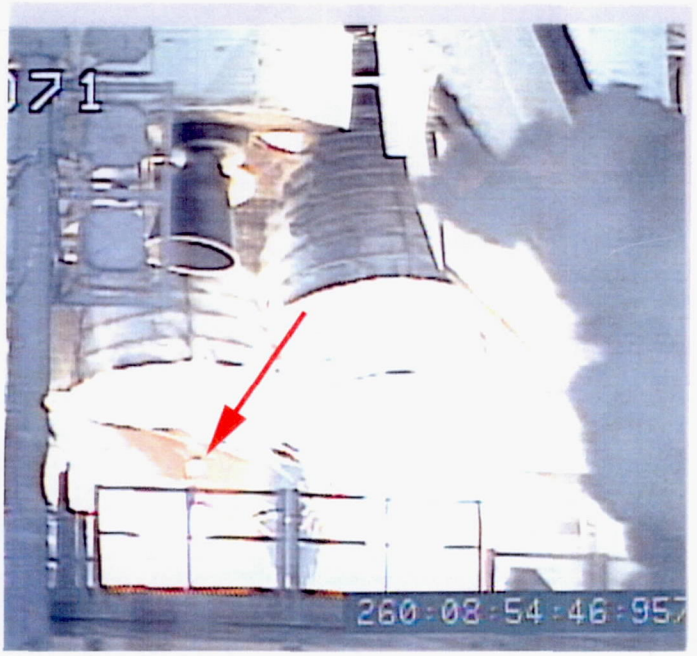

Figure 2.1.1.1 Debris Aft of the SSMEs During SSME Ignition

Several pieces of light-colored debris (probable RCS paper) were seen aft of the SSMEs during SSME ignition (08:54:45.623, 08:54:46.957 UTC).

2.1.2 Debris Near the Time of SRB Ignition

As on previous missions, multiple pieces of debris were seen near the time of SRB ignition.

2.1.2.1 Debris Seen Near FSS During Liftoff
(Camera: E5)

Multiple pieces of debris were seen falling along the FSS during liftoff..

2.1.2.2 Debris Seen North of the Launch Vehicle at Liftoff
(Cameras: KTV4, E52, E62)

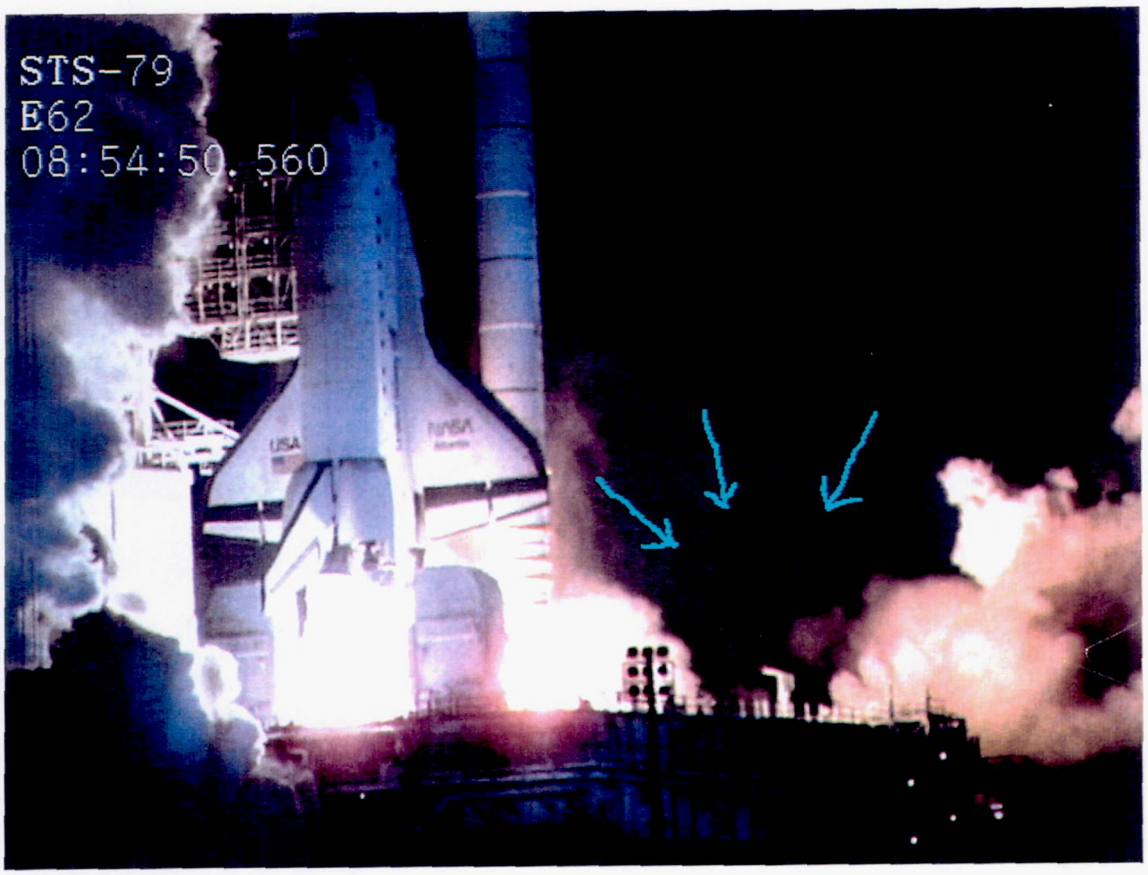

Figure 2.1.2.1 Debris Seen North of the Launch Vehicle at Liftoff

Multiple pieces of debris (at least eight) from the SRB flame trench area (possibly SRB throat plug material) were seen north of the launch vehicle at liftoff (08:54:50.560 UTC). Debris north of the launch vehicle at liftoff has been seen on previous missions.

2.1.3 Debris After Liftoff
(Cameras: E57, E59)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) after liftoff on the launch tracking views.

2.1.3.1 Debris Seen in SSME Exhaust Plumes
(Cameras: E54, E207, E213, E222, E223, E224)

Multiple pieces of debris (probably RCS paper) were seen in the SSME exhaust plumes between 08:54:54.0 and 08:55:23.8 UTC. Debris in the SSME exhaust plumes has been seen on previous missions.

2.1.3.2 Debris Falls from ET/Orbiter Umbilical
(Cameras: E54, E212, E223, E224)

Multiple pieces of debris originating from the ET/Orbiter umbilical area (probable ice debris) were seen falling aft of the launch vehicle between 08:54:53.9 and 08:55:03.6 UTC. Debris from the ET/Orbiter umbilicals has been seen on previous missions.

2.1.3.3 Debris Falls Along SRB Plumes
(Cameras: KTV21, ET207, ET208, E212, E223)

Figure 2.1.3.3 Debris Falls Along SRB Plumes

Multiple pieces of debris (at least nine), possible SRB aft skirt instafoam, were seen falling aft along the SRB exhaust plume during ascent (08:55:54.927 UTC to 08:56:15.281 UTC). A single piece of debris was seen falling aft along the SRB exhaust plume at 08:56:49.7 UTC. Debris aft of the launch vehicle during ascent has been seen on previous missions.

2.1.3.4 Slag Debris Seen Exiting the SRB Exhaust Plumes
(Cameras: ET204, ET207, ET208)

Figure 2.1.3.4 Slag Debris Seen Exiting the SRB Exhaust Plumes

Multiple pieces of slag debris were seen falling from the SRB exhaust plumes and SRB nozzles before, during, and after SRB separation. Slag debris at SRB separation has been seen on previous missions, particularly on nighttime views.

2.2 MOBILE LAUNCH PLATFORM (MLP) EVENTS

2.2.1 Vapor Seen Coming from the +Z ET Intertank Vent
(Camera: E34)

Vapor was seen coming from the +Z ET intertank vent at liftoff (08:54:50.0 UTC). Vapors from this vent during liftoff have been seen on previous missions. No follow-up action was requested.

2.2.2 Orange Vapor Seen During SSME Ignition
(Cameras: OTV051, OTV063, OTV070, OTV071, E1, E2, E3, E5, E16, E19, E20, E36, E52, E63)

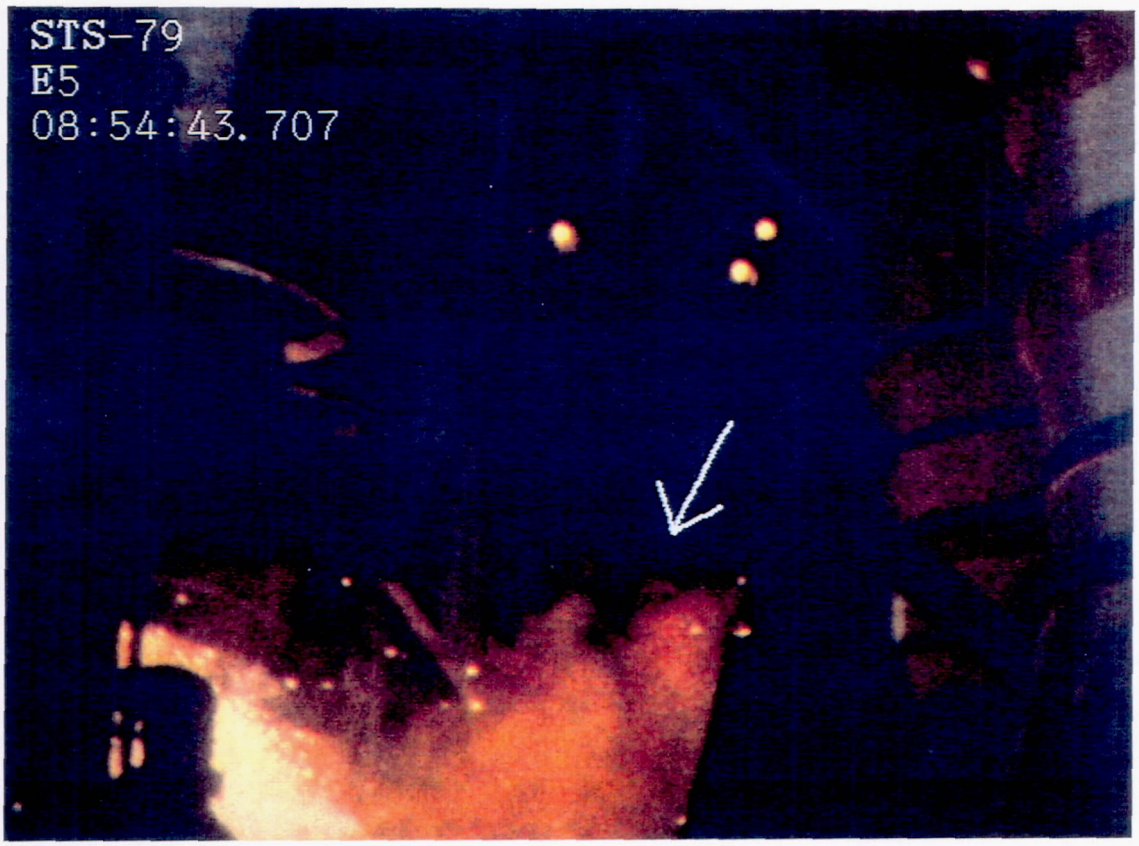

Figure 2.2.2 Orange Vapor Seen During SSME Ignition

Orange vapors, probably free burning hydrogen, were seen above the SSME rims, near the body flap, and near the base of the vertical stabilizer during SSME ignition (08:54:43.7 UTC). Orange vapors have been seen on previous missions. Camera E5 provides a good view of what appears to be a significant amount of orange vapor near the body flap during engine start-up. No follow-up action was requested.

2.2.3 SSME Mach Diamond Formation
(Camera: E222)

The SSME Mach diamonds formed in sequence. The times of the Mach diamond formation were:

SSME #3: 08:54:45.743 UTC.
SSME #2: 08:54:45.864 UTC.
SSME #1: 08:54:45.964 UTC.

2.2.4 TPS Erosion on Left RCS Stinger and Base Heat Shield
(Camera: E20)

A small area of TPS erosion was seen on the base of the left RCS stinger during SSME ignition. Two additional areas of base heat shield erosion were seen near the left OMS nozzle at approximately the same time. The TPS erosion was less than that generally seen on previous mission films. No follow-up action was requested.

2.2.5 Orange Flash Seen in SSME Exhaust Plume Prior to Liftoff
(Cameras: E2, E3)

An orange-colored flash was seen in the SSME #1 exhaust plume prior to liftoff (08:54:47.412 UTC). Flashes in the SSME exhaust plumes have been seen on previous missions. No follow-up action was requested.

2.2.6 Bolt Hang-Up at Holddown Post M-3
(Camera: E10)

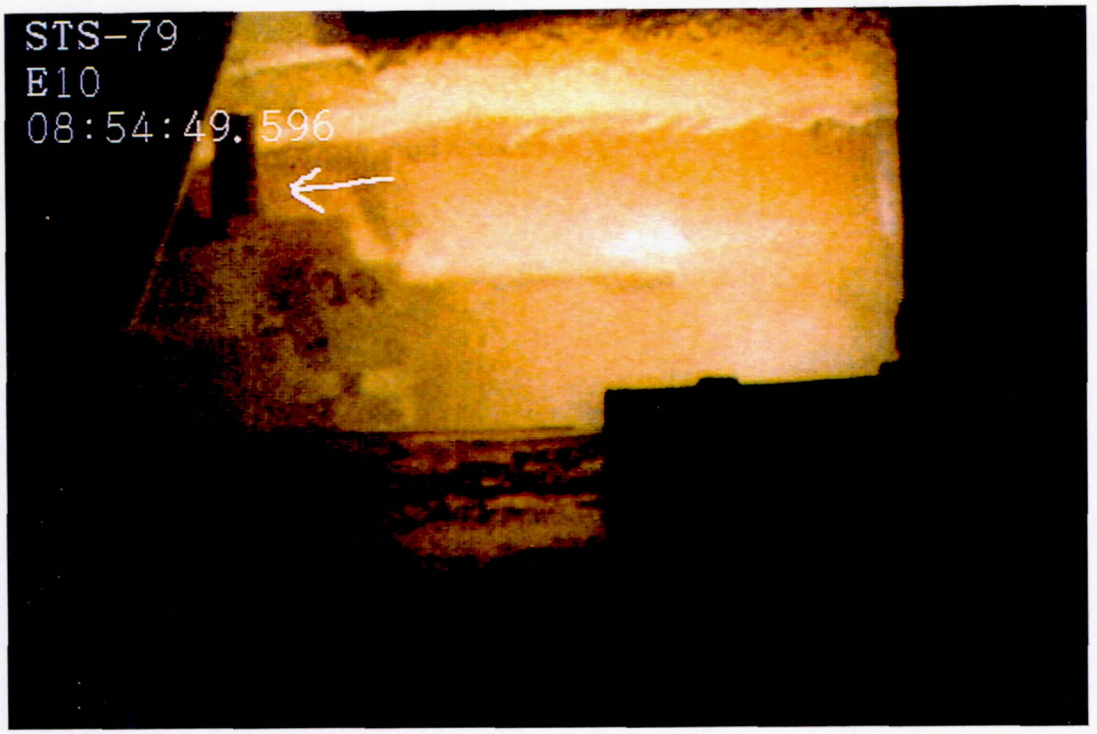

Figure 2.2.7 Bolt Hang-Up at Holddown Post M-3

A bolt hang-up was seen at the RSRB holddown post M-3 at liftoff (08:54:49.594 UTC). No debris fragments were seen near the DCS during the hang-up and bolt release. SRB holddown bolt hang-ups have been seen on five of the last seven previous missions. See Table 2.2.7. No follow-up action was requested.

MISSION	LOCATION OF HANG-UP
STS-34	RSRB holddown post M-2
STS-33	RSRB holddown post M-3
STS-39	RSRB holddown post M-1
STS-43	LSRB holddown post M-7
STS-45	RSRB holddown post M-4
STS-50	RSRB holddown post M-4
STS-46	LSRB holddown post M-7
STS-53	RSRB holddown post M-1
STS-73	RSRB holddown post M-2
STS-75	LSRB holddown post M-5
STS-76	LSRB holddown post M-5
STS-78	LSRB holddown post M-5
STS-79	RSRB holddown post M-3

Table 2.2.7 SRB Holddown Post Bolt Hang-Ups Seen on Previous Missions

2.2.7 White-Colored Vapor Seen at Liftoff
(Camera: OTV063)

White-colored vapor was seen between the RSRB and the ET aft dome at liftoff (08:54:49.66 UTC). This vapor was not seen on launch films and was probably vapor from the TSM T-0 umbilical disconnect. No follow-up action was requested.

2.3 ASCENT EVENTS

2.3.1 Vapor Seen from the Vertical Stabilizer Vent
(Camera: E54)

Vapor was seen coming from the vent on the trailing edge of the vertical stabilizer during liftoff (08:54:54.2 UTC). Vapor from this vent during liftoff has been seen on previous missions. No follow-up action was requested.

2.3.2 Contrails Seen During Ascent
(Cameras: E57, E59, E222)

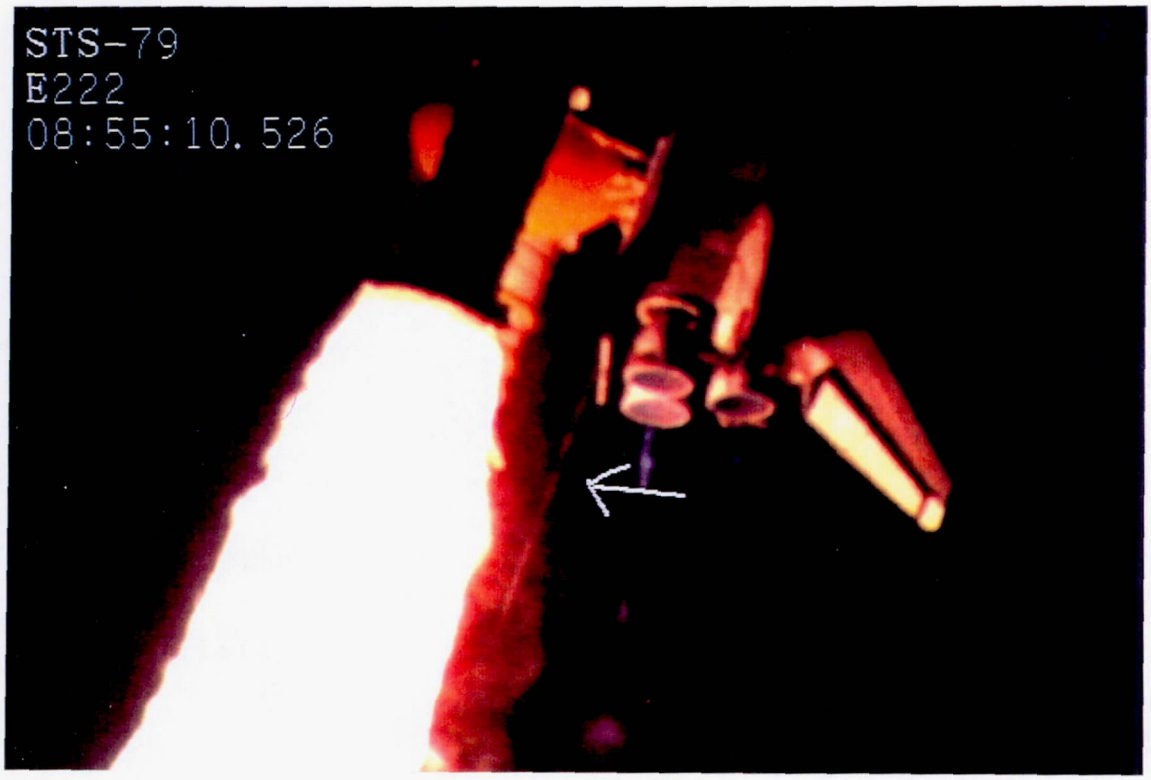

Figure 2.3.2 Contrail Seen During Ascent

A faint white (intermittent) streak first seen near the center of the right outboard elevon trailed aft of the right wing between 08:55:10.021 and 08:55:10.9 UTC. This is probably the same white streak that appeared near the body flap on camera view E222 between 08:55:09.8 and 08:55:10.8. On camera E57, a contrail was seen originating from the left wing tip at 08:55:06.846 UTC. The white streak was probably a contrail of visible moisture. No follow-up action was requested.

2.3.3 Flares in SSME Exhaust Plume
(Cameras: ET207, E222)

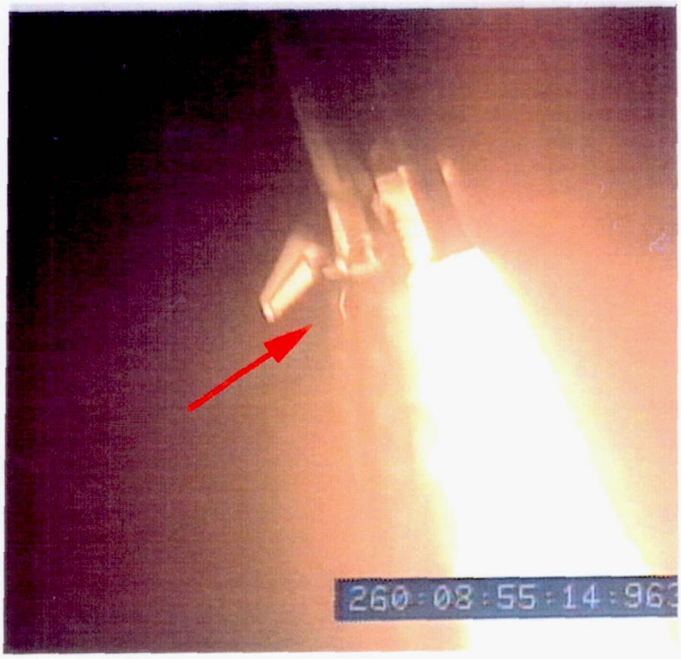

Figure 2.3.3 Flare in SSME Exhaust Plume

Two orange-colored flares, probably debris induced, were seen in the SSME exhaust plume after the roll maneuver (08:55:14.963, 08:55:14.981 UTC). Flares in the SSME exhaust plumes have been seen on previous missions. No follow-up action was requested.

2.3.4 Body Flap Motion after Roll Maneuver
(cameras: ET207, E207, E212, E213, E223)

Body flap motion was seen after the roll maneuver (08:55:22 - 08:55:50 UTC). The body flap movement (amplitude and frequency) appeared similar to previous missions. No follow-up action was requested.

2.4 ONBOARD PHOTOGRAPHY OF THE EXTERNAL TANK (DTO-312)

2.4.1 Analysis of the Umbilical Well Camera Films (Task #2)

Two rolls of STS-79 umbilical well camera film were acquired: the 16mm film (5mm lens) and the 16mm film (10mm lens) from the LH2 umbilical. The 35mm film from the LO2 umbilical was not usable due to darkness during ET separation.

Good coverage of the LSRB separation was acquired. As on previous missions, numerous light-colored pieces of debris (probably insulation) and dark debris (probably charred insulation) were seen throughout the SRB film sequence. Typical ablation and charring of the LH2 umbilical electric cable tray and the -Y ET/SRB vertical strut were seen. Vapor and multiple pieces of light-colored debris were seen near the LSRB aft attach prior to ET separation.

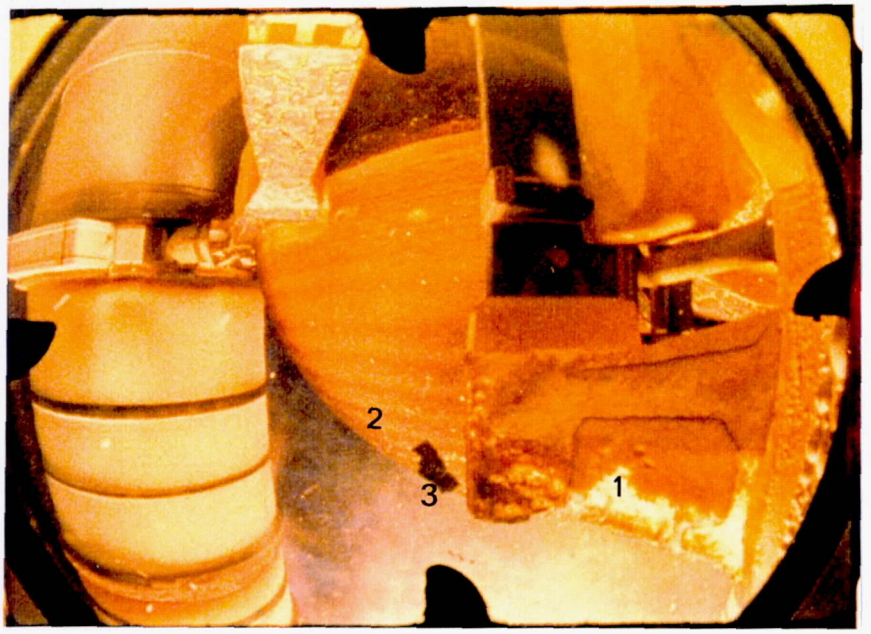

Figure 2.4.1 LSRB/ET Aft Dome

TPS ablation was noted on the LH2 electric cable tray (**1**). Ablation to the ET aft dome TPS was seen (**2**). A piece of dark-colored debris (probably charred TPS material) was seen near the LH2 electrical tray (**3**). Blistering of the LH2 ET/Orbiter umbilical fire barrier coating was typical.

2.4.2 Analysis of Handheld Photography of the ET (Task #3)

One roll of handheld photography was taken using the Nikon F4 with the 300 mm lens plus 2X extender. An early OMS-2 pitch maneuver was performed to bring the external tank into view. Fourteen usable frames were acquired for analysis.

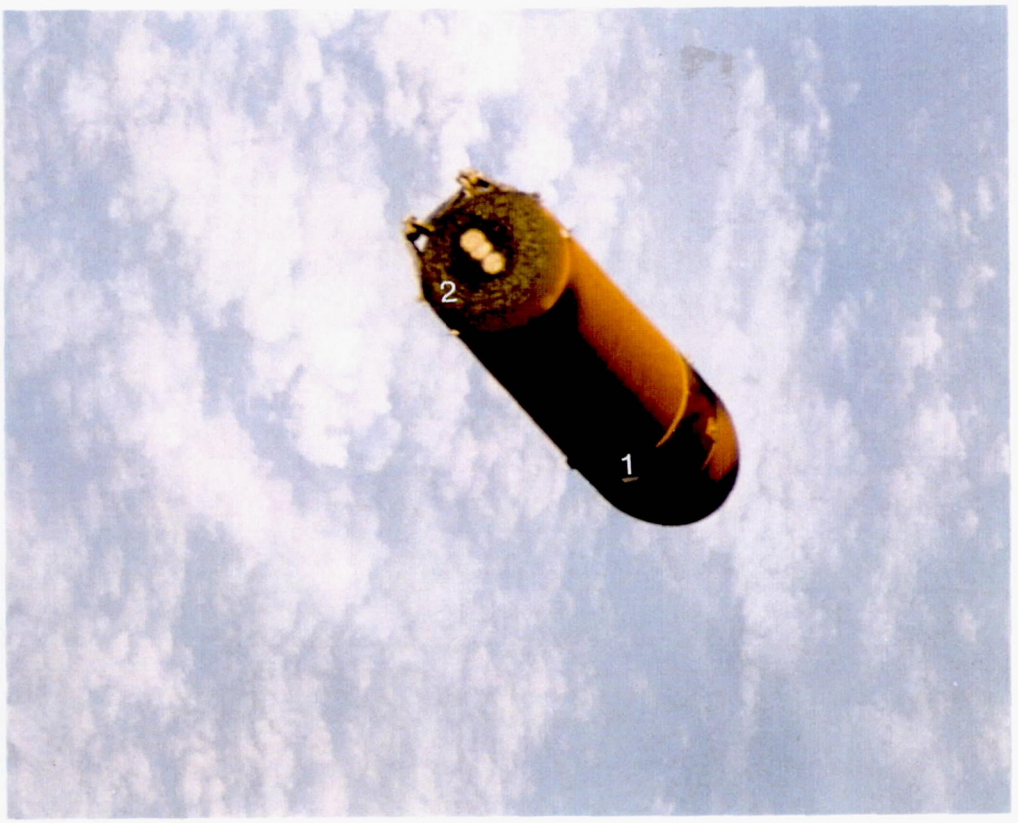

Figure 2.4.2 (A) Handheld View of the External Tank

STS-79 was the first flight of the dark composite intertnk access door (which replaces the previously used foam-covered door). The new composite intertank access door appears in good condition in the handheld camera view above (1).

The new TPS agent 24-57 was used for the first time on the STS-79 hydrogen (H2) tank aft dome. Multiple faint, light-colored marks are visible on the charred H2 tank aft dome TPS on the handheld camera view shown in Figure 2.4.2 (A), annotation (2).

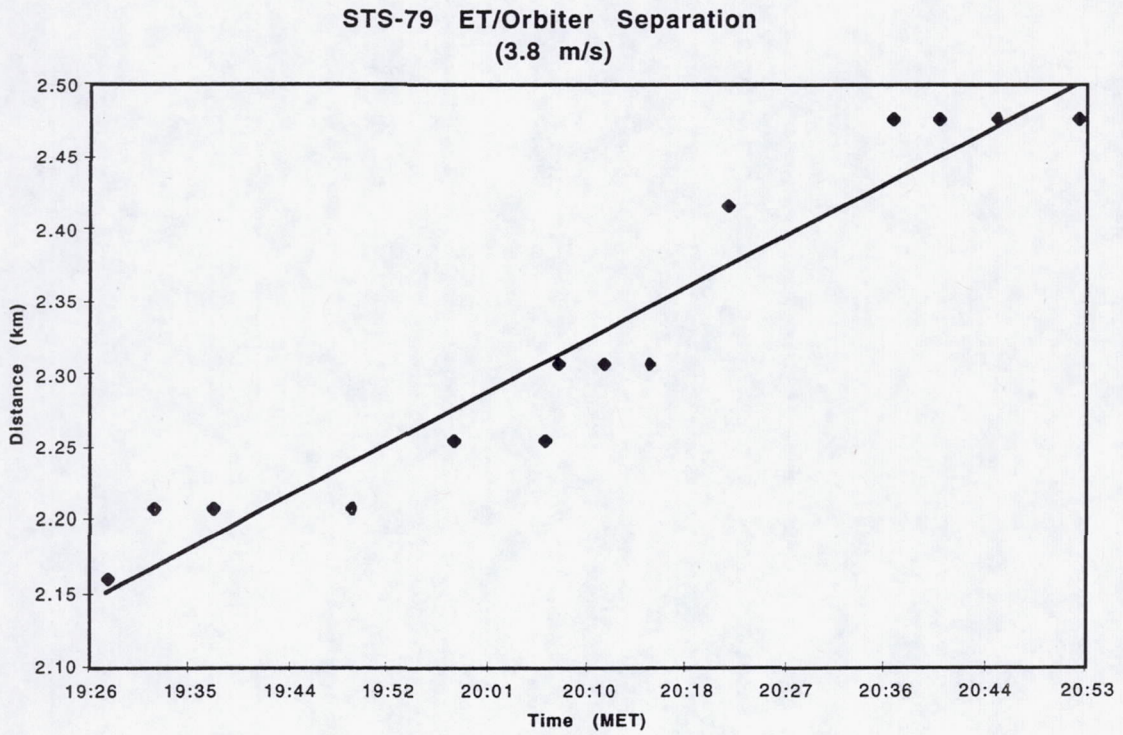

Figure 2.4.2 (B) ET Separation Velocity

The distance of the external tank was calculated over a fourteen-frame sequence using the handheld photography. The external tank was calculated to be a distance of 2.2 km away from the Orbiter at 19:28 MET. The tank was calculated 84 seconds later (20:52 MET) to be at a distance of 2.5 km. The tank separation velocity was determined to be 3.8 m/s. The separation velocity was similar to previous mission measurements. The tank tumble rate was determined to be 1.1 deg/sec. The roll rate of the ET was too small to measure during the 84 second acquisition period of the handheld photography.

2.5 ON ORBIT EVENTS

2.5.1 Debris Seen on Orbit 8

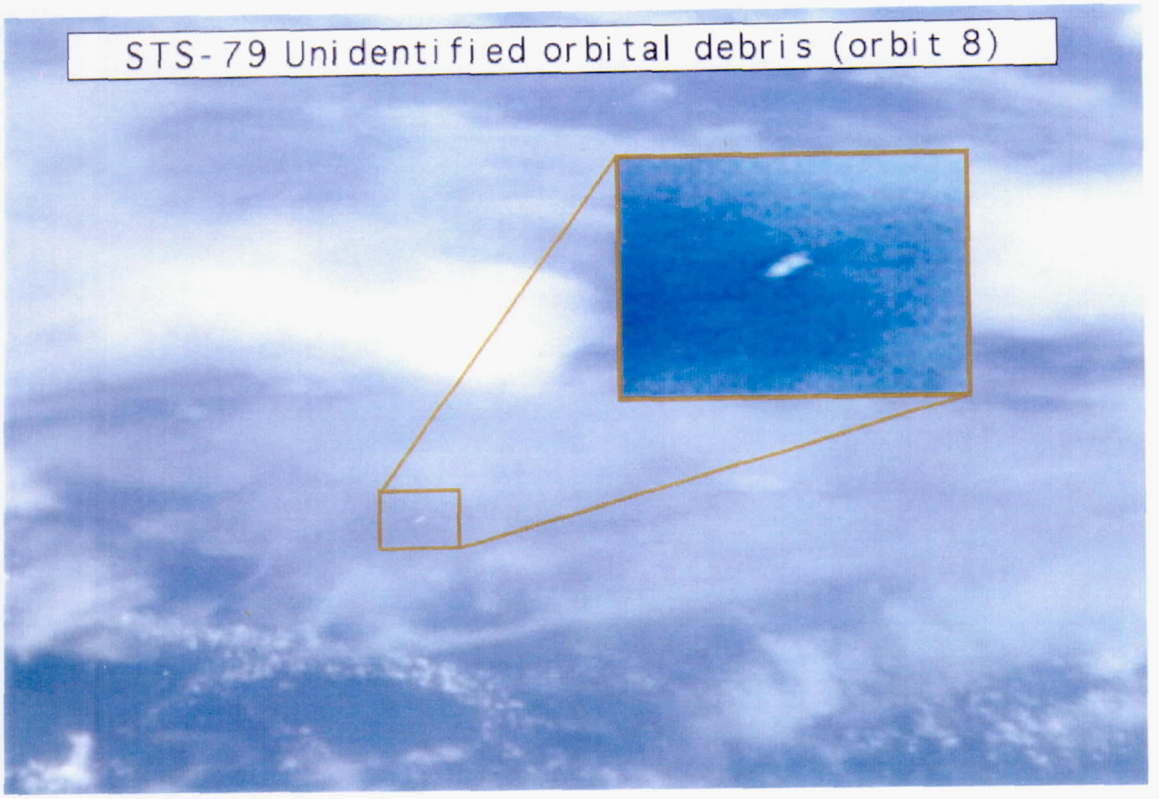

Figure 2.5.1 Debris Seen on Orbit 8

Analysis of a five minute segment of STS-79 downlink taken 11 hours after launch (260:19:58 UTC), revealed a bright-colored piece of debris moving in proximity to the Orbiter at a lower altitude and a slightly different inclination. The debris appeared uniformly white in color, oblong in shape (L/D = 3), and was gyrating freely with a period of approximately 0.7 seconds. Attempts to determine the size of the debris were inconclusive.

2.5.2 Debris Seen from Payload Bay Camera after Mir Docking

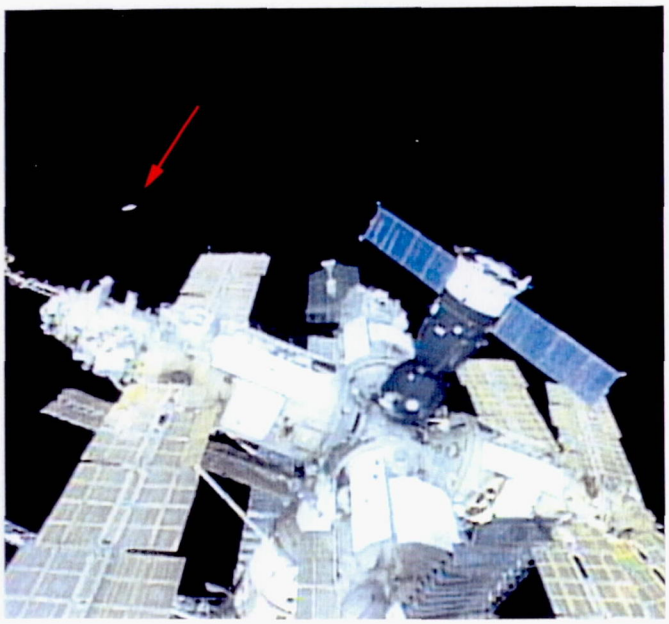

Figure 2.5.2 Debris Seen from Payload Bay Camera after Mir Docking

A reflective-appearing piece of debris was seen from Orbiter payload bay camera B after docking to the Mir space station. The debris did not appear to contact the Orbiter or the Mir Space Station. No follow-up action was requested.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis (Task #1)

The main and nose gear sink rates of the Orbiter were determined using landing films over a one-second time period prior to main gear touchdown.

The measured main gear sink rate values were found to be below the maximum allowable values of 9.6 ft/sec for a 211,000 lb. vehicle and 6.0 ft/sec for a 240,000 lb. vehicle (the landing weight of the STS-79 Orbiter was reported to be 215,000 lb.). The sink rate measurements for STS-79 are given in Table 2.6.1. In Figure 2.6.1(A), and 2.6.1(B), the trend of the measured data points for the film image data is illustrated.

Prior to Touchdown (1/4 Second)	Sink Rate: Film
Main Gear	3.4 ft/sec
Nose Gear	4.0 ft/sec

Table 2.6.1 Sink Rate Measurements

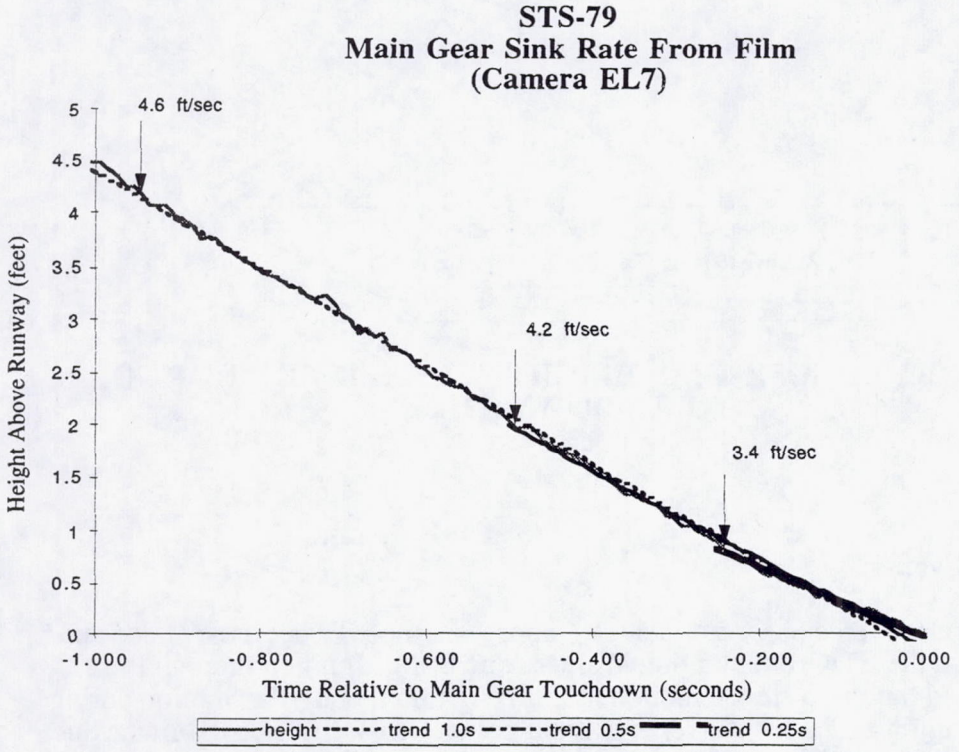

FIGURE 2.6.1(A) **MAIN GEAR HEIGHT VERSUS TIME PRIOR TO TOUCHDOWN (FILM)**

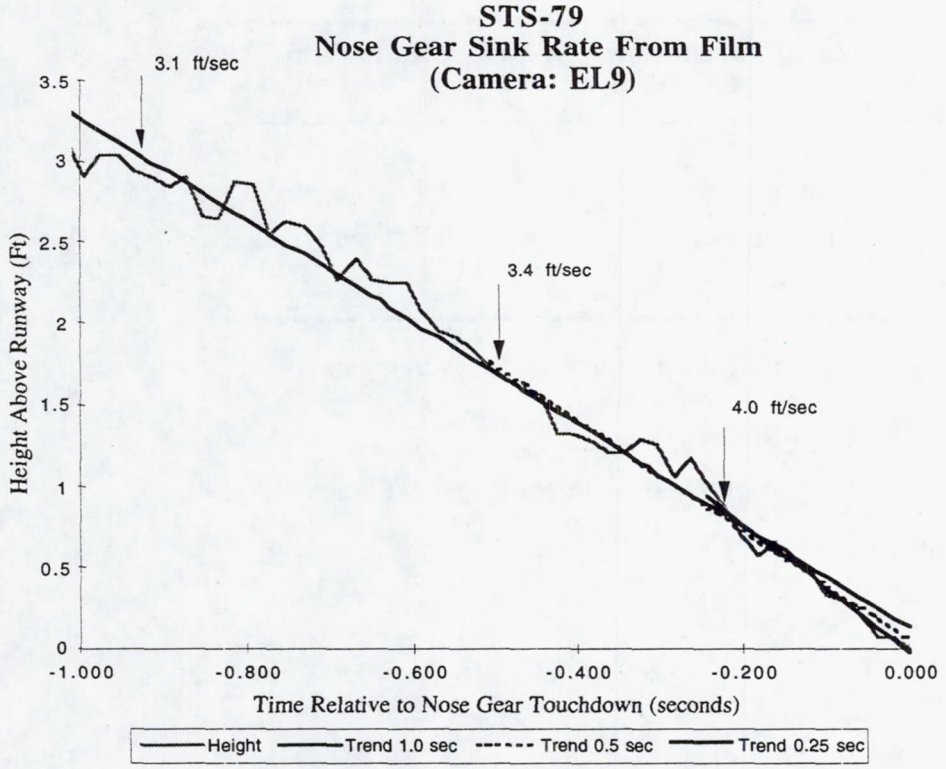

FIGURE 2.6.1(B) **NOSE GEAR HEIGHT VERSUS TIME PRIOR TO TOUCHDOWN (FILM)**

2.7 OTHER

2.7.1 Normal Events:

Other normal events observed include: vapor from the ET vent louvers, ice and vapor from the ET/Orbiter umbilical areas from SSME ignition through liftoff, inboard and outboard elevon motion at SSME ignition, body flap motion during SSME ignition and at liftoff, vertical stabilizer motion at liftoff, SRB flame duct and MLP debris at liftoff, ET twang, multiple pieces of light-colored debris falling from the LH2 and LO2 TSM T-0 umbilicals prior to and at disconnect, ET aft dome outgassing and vapor off the SRB stiffener rings during liftoff, vapor and ice from the GUCP area during ET GH2 vent arm retraction, acoustic waves at liftoff, debris in exhaust cloud after liftoff, expansion waves after liftoff, roll maneuver, white flashes near the SRB exhaust plume after liftoff, linear optical effects, condensation around the launch vehicle after the roll maneuver, ET aft dome charring, recirculation, SRB plume brightening prior to SRB separation, SRB separation, and SRB slag material after SRB separation.

Normal Pad Events Observed Were:

Hydrogen burn ignitor operation, FSS deluge water operation, GH2 vent arm retraction, MLP deluge water operation, and sound suppression system water operation. J-Pipe water leaks were seen near the LSRB holddown posts M-8.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

STS-79 Photographic Analysis Report

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Introduction

The launch of space shuttle mission STS-79, the seventeenth flight of the orbiter Atlantis, occurred on September 16, 1996, at 3:54 A.M. Central Daylight Time from launch complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Launch time was reported as 96:260:08:54:48.991 Universal Coordinated Time (UTC) by the MSFC Flight Evaluation Team. Photographic and video coverage was evaluated to determine proper operation of the flight hardware. Video and high-speed film cameras providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39A perimeter sites, Eastern Test Range tracking sites and onboard the vehicle.

Engineering Analysis Objectives

The planned engineering photographic and video analysis objectives for STS-79 include, but were not limited to the following:

- Verification of cameras, lighting and timing systems.
- Overall propulsion system coverage for anomaly detection and structural integrity.
- Determination of SRB PIC firing time and SRB separation time.
- Verification of Thermal Protection System (TPS) integrity.
- Correct operation of the following:
  - SSME ignition
  - SRB debris containment system
  - LH2 and LO2 17-inch disconnects
  - Ground umbilical carrier plate (GUCP)
  - Free hydrogen ignitors
  - Booster separation motors (BSM)

There were no special test objectives for this mission.

Camera Coverage Assessment

The following table illustrates the camera coverage received at MSFC for STS-79.

	16mm	35mm	Video
MLP	17	0	4
FSS	5	0	3
Perimeter	0	2	6
Tracking	0	14	11
Onboard	2	1	0
Totals	24	17	24

Total number of film and videos received to date: 65

An individual motion picture camera assessment is provided as Appendix A. Appendix B contains detailed assessments of the video products received at MSFC.

Ground Camera Coverage

The launch of STS-79 occurred during the night time which provided for dark film images. This launch was the first time the POCS (Photo Optical Control System) was used. Three cameras (E4, E11, and E60) experienced blown fuses and provided no data. A computer problem causes a short run on item E52. Erratic tracking of the vehicle on item E220 provided reduced data.

Onboard Camera Coverage

Coverage of the ET after separation by the astronauts using the 35mm camera provided fourteen good quality views of the ET. The -Z, +Y, and +Z axes were imaged along with the aft dome.

The orbiter's 16mm LH2 umbilical well cameras recorded the SRB separation event. The films from both the 16mm and 35mm cameras were too dark to record the ET separation event.

Anomalies

[redacted] A stud hang-up on the SRB holddown post M-3 was observed during liftoff from the MLP. This event appeared typical of previous stud hang-ups. This event was recorded by camera item E10.

Observations

The data from this launch appeared typical of previous night time launches.

[redacted] Streaks were observed in the SSME plumes prior to liftoff from the MLP. Several cameras recorded a bright white streak in the ME-2 plume at 08:54:45.75 UTC.

Vapors were again observed near the intertank +Z aero vent at liftoff from camera E34. These types of vapors have been previously observed.

[redacted] A significant amount of "slag" from the SRM plumes was observed being emitted during ascent and during SRB separation. This amount of visible "slag" is believed to be a result of the dark sky conditions and the camera viewing angles of the northerly flight path. The amount and frequency of "slag" particles is within previously recorded data.

[redacted] Loose thermal curtain tape during early ascent was recorded by tracking cameras E207 and E222. This tape attributes to the debris that is typically observed falling from the vehicle during ascent.

[redacted] The ET aft dome appears to have experienced the expected amounts of charring and ablation with no visible problems during ascent. STS-79 was the first use of the NCFI 24-57 TPS on the aft dome. Also, the new composite intertank door appears to be in good condition. Two small TPS divots near the +Z and -Z axis along the hydrogen tank/intertank scarf joint were visible.

Engineering Data Results

T-Zero Times

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5, and M-6. These cameras record the explosive bolt combustion products.

Holddown Post	Camera Position	Time (UTC)
M-1	E9	08:54:49.00
M-2	E8	(image to dark)
M-5	E12	08:54:49.001
M-6	E13	08:54:49.000

SRB Separation Time

SRB separation as recorded by observations of the BSM combustion products from film is estimated to be 08:56:51.04 UTC. This time was recorded by long-range tracking camera E208.

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13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-79. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs and infrared scanned data during cryogenic loading of the vehicle, followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-79 and the resulting effect on the Space Shuttle Program.

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